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What of environment, market and prying eyes?

OBD-2 DIY project

Spectrum Analyser

2.4 GHz Neighbourhood Watch

On the scoreboard

15 multimeters with a serial connection

Linux 'Scope µCLinux and U-Boot | **Valve Amplifier** that nostalgic sound |
Inductance Meter from 100 nH to 100 mH in a jiffy |
AVR Flash Progger component count = 7 |
Vertical Speed Indicator whistles from on high |

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Stereo VU and Peak Meter Kit

KC-5447 £20.50 + post & packing

Accurately monitor audio signals to prevent signal clipping and ensure optimum recording levels. This unit is very responsive and uses two 16-segment bargraphs to display signal levels and transients peaks in real time. There are a number of display options to select, and both the signal threshold and signal level calibration for each segment are adjustable. Kit supplied with PCBs, LCD and all electronic components. Accuracy within 1dB for signals above -40dB.

- Case not included use HB-6082 £2.95

Requires 9-12VDC wall adaptor (Maplin #JC91Y £14.99)

Short form kit

Battery Zapper MKII

KC-5427 £29.00 + post & packing

This kit attacks a common cause of failure in wet lead acid cell batteries: sulphation. The circuit produces short bursts of high level energy to reverse the damaging sulphation effect. This new improved unit features a battery health checker with LED indicator, new circuit protection against badly sulphated batteries, test points for a DMM and connection for a battery charger. Kit includes case with screen printed lid, PCB with overlay, all electronic components and clear English instructions. Suitable for 6, 12 and 24V batteries

- Powered by the battery itself

Improved model for 2007

50MHz Frequency Meter MKII Kit

KC-5440 £20.50 + post & packing

This compact, low cost 50MHZ Frequency Meter is invaluable for servicing and diagnostics. This upgraded version, has a prescaler switch which changes the units from Mhz to GHz, kHz to MHz and Hz to kHz, and has 10kHz rounding to enable RC modellers to measure more accurately. Kit includes PCB with overlay, enclosure, LCD and all electronic components.

Other features include:

- 8 digit reading (LCD)
- Prescaler switch
- Autoranging Hz, kHz or MHz
- 3 resolution modes including 10kHz rounding, 0.1Hz up to 150Hz, 1Hz up to 16MHz and 10Hz up to 16MHz

Jacobs Ladder High Voltage Display Kit

KC-5445 £11.75 + post & packing

With this kit and the purchase of a 12V ignition coil (available from auto stores and parts recyclers), create an awesome rising ladder of noisy sparks that emits the distinct smell of ozone. This improved circuit is suited to modern high power ignition coils and will deliver a spectacular visual display. Kit includes PCB, pre-cut wire/ladder and all electronic components.

- 12V car battery, 7AH SLA battery or 5Amp DC power supply required

Powertool Battery Charger Controller

KC-5436 £11.75 + post & packing

Enhance the performance of the charger supplied with your power tool with this controller. It incorporates charge timeout, min and max temperature monitoring, Delta charge detection, power and charge LED indicator, adjustable Delta V, temperature settings, and optional adjustable trickle charge. Suits both Ni-Cd and Ni-MH cells. Kit includes PCB with overlay, case, all electronic components and clear English instructions.

DC Relay Switch

KC-5434 £4.50 + post & packing

An extremely useful and versatile kit that enables you to use a tiny trigger current - as low as 400µA at 12V to switch up to 30A at 50VDC. It has an isolated input, and is suitable for a variety of triggering options. The kit includes PCB with overlay and all electronic components with clear English instructions.

Voltage Regulator Kit

KC-5446 £4.50 + post & packing

This handy voltage regulator can provide up to 1,000mA at any voltage from 1.3 to 22VDC. Ideal for experimental projects or as a mini bench power supply etc. Kit supplied with PCB and all electronic components.

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Expect 10-14 Days For Air parcel delivery

Programmable High Energy Ignition System

Ignition System

KC-5442 £26.25 + post & packing

This advanced and versatile ignition system can be used on both two & four stroke engines. The system can be used to modify the factory ignition timing or as the basis for a stand-alone ignition system with variable ignition timing, electronic coil control and anti-knock sensing.

Features:

- Timing retard & advance over a wide range
- Suitable for single coil systems
- Dwell adjustment
- Single or dual mapping ranges
- Max & min RPM adjustment
- Optional knock sensing
- Optional coil driver
- Kit supplied with PCB, diecast case, abd all electronic components

Hand Controller

KC-5386 £25.95 + post & packing

This LCD hand controller is required during the initial setting-up procedure. It plugs into the main unit and can be used while the engine is either running or stopped. Using this Hand Controller, you can set all the initial parameters and also program the ignition advance/retard curve. Kit supplied with silk screened and machined case, PCB, LCD, and all electronic components.

Ignition Coil Driver

KC-5443 £13.00 + post & packing

Add this ignition coil driver to the KC-5442 Programmable Ignition System and you have a complete stand-alone ignition system that will trigger from a range of sources including points, Hall Effect sensors, optical sensors, or the 5 volt signal from the car's ECU. Kit includes PCB with overlay and all specified components.

- Kit supplied with PCB, and all electronic components

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DSO may even be used stand-alone to share data with colleagues, students or customers. Waveforms may be exported as portable image files or live captures replayed on other PCs as if a BitScope was locally connected.

BitScope DSO supports all current BitScope models, auto-configures when it connects and can manage multiple BitScopes concurrently. No manual setup is normally required. Data export is available for use with third party software tools and BitScope's networked data acquisition capabilities are fully supported.

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leading the way

Measuring — but what exactly?

I am from a century when you could safely say that a steering wheel, wheels, an engine, seats and a chassis are among the main parts that constitute a car. Although I also remember lots of tinkering, I always felt 'owner of the vehicle'. I cheerfully adjusted the eight valves to match my very own preferences and never failed to keep the car going one way or another. If we are to believe car tuning expert Chris Vossen of the Elektor design lab, my concept of a car is antiquated. The car, or should that be the onboard computer, pushes the driver out of his seat and takes over 'big time'.

The OBD-2 Analyser described in this issue will inform you in plain language what's happening under the bonnet. Taking that a bit further, OBD-2 supplies only a subset of the massive amount of information your car is processing (and recording?) and your car dealer will not spill the beans either when asked for the full set of data. So, along this line of thinking, what if car computers get smarter still and start to record route information and vehicle speed? This begs the question of who owns the information. You / the car dealer / the hacker / the car manufacturer / the computer manufacturer / MOT? *

The digital multimeter is a trusty test instrument owned by almost any electronics enthusiast. It comes in many shapes and sizes, but versions with a serial interface are of particular interest. We tested a number of these instruments, spotted differences and collected the results in an article.

Just in case you have no practical interest in OBD-2 or a new multimeter, may I suggest a fine class-A valve amplifier? A solid design using well-established technology and components, the amp is sure to take you back to the previous century in more than one way.

Wisse Hettinga
International Editor

* cross out what's not applicable

Meters with

A multimeter is the standard measurement tool for every electronics hobbyist. You can use them to measure voltages, currents and resistances. Many modern multimeters can also measure capacitance and frequency. A few of them

46 Stand-alone OBD Analyser

This handy analyser (available as a kit) makes a simple job of rummaging through the information stored by the client–accessible part of your car's computer. It works with all current OBD-2 protocols and can read and erase trouble codes stored in the vehicle and reset the MIL display. All this without the help of a PC or a visit to a service station.

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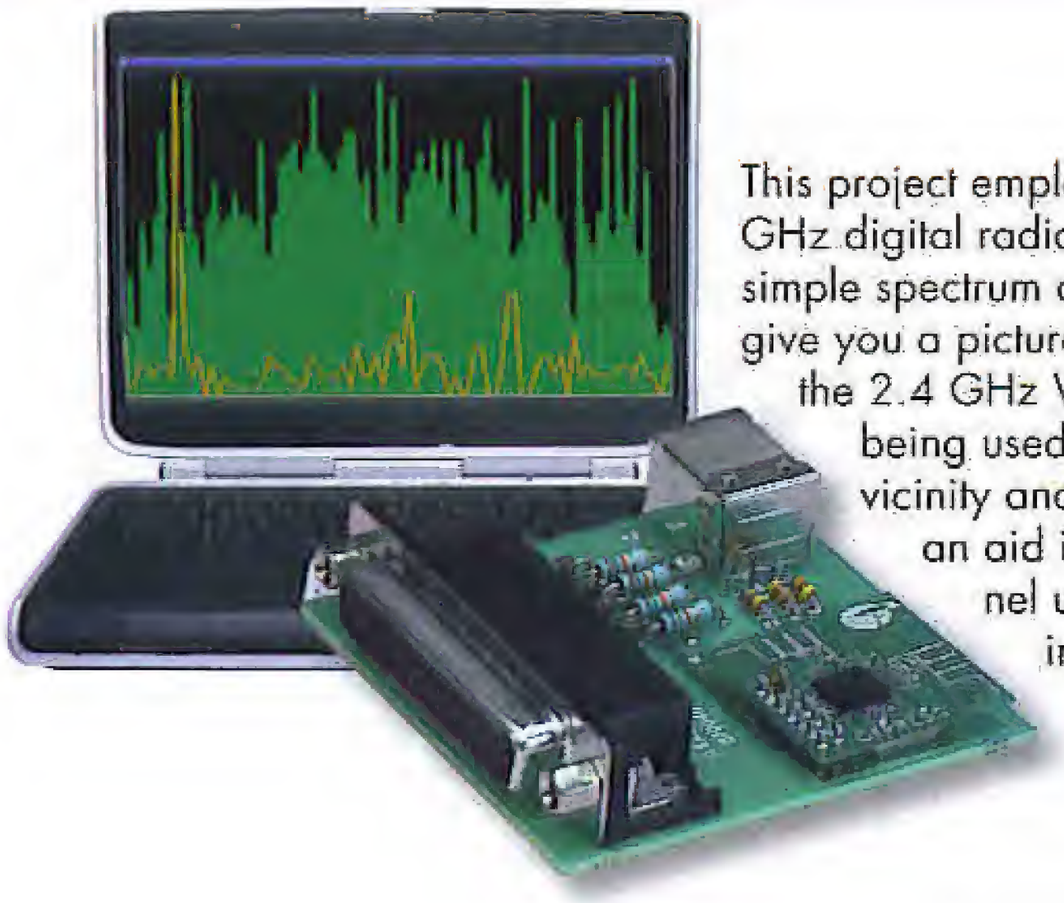
even have the facility of a PC connection for data logging. In this article we give an overview of (almost) all devices that are currently available with this feature.

26 2.4 GHz WiFi Spectrum Analyser



This project employs a Cypress 2.4 GHz digital radio chip to make a simple spectrum analyser. This can give you a picture of which parts of the 2.4 GHz WiFi spectrum are being used in your immediate vicinity and even be used as an aid in optimising channel use and detection of interfering devices.

38 Tube Sound

It is remarkable that triode output stages still occupy an important place in high-end audio amplifiers. Triode amplifiers are often very expensive. The design presented here is based on a combination of optimal quality and reasonable construction cost. Keywords: 6AS7 power triodes and a matched output transformer.

projects

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CANSPI Board - Make CAN network with SPI interface.

RS485 Board - Connect devices into RS-485 network.

Serial Ethernet - Make ethernet network with SPI interface (ENC28J60)

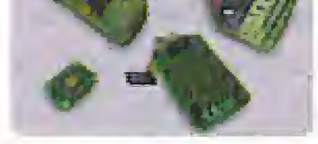
IrDA2 Board - Irda2 serves as wireless RS232 communication between two MCUs

CF Board - Easy way to use Compact Flash in your design

MMC/SD Board - Easy way to use MMC and SD cards in your design

EEPROM Board - Serial EEPROM board via I2C interface

RTC Board - PCF8563 RTC with battery backup



ADC Board - 12-bit analog-to-digital converter (ADC) with 4 inputs

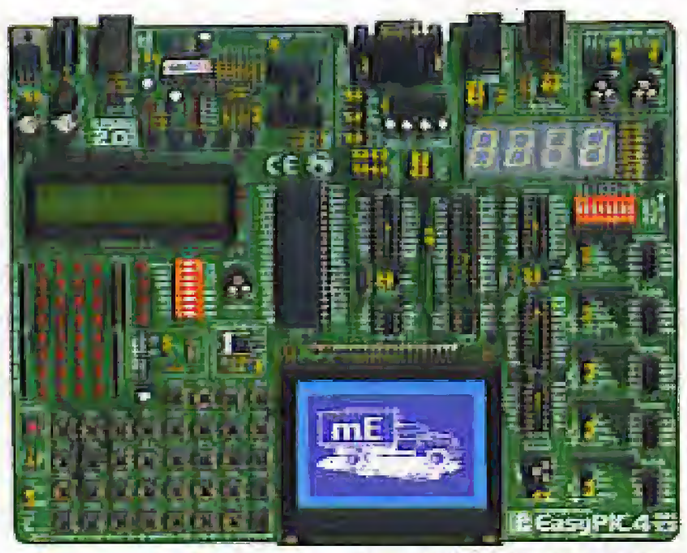
DAC Board - 12-bit digital-to-analog converter (DAC) with SPI

Keypad 4x4 Board - Add keypad to your application

Accel Board - Accel. is an electronic device that measures acceleration forces

EasyPIC4 Development Board

with on-board USB 2.0 programmer and mikroICD



3 in 1 DEVELOPMENT SYSTEM

HARDWARE ICD ON-BOARD USB 2.0 ON-BOARD PROGRAMMER HIGH PERFORMANCE DEVELOPMENT BOARD

EasyPIC4 development board: Following tradition of its predecessor EasyPIC3 as one of the best PIC development systems on the market, EasyPIC4 has more new features for the same price. The system supports 8-, 14, 18, 20, 28 and 40 pin PIC microcontrollers (it comes with a PIC16F877A).

mikroICD is a highly effective tool for the Real-Time debugging on a hardware level. The ICD debugger enables you to execute a mikroC/mikroPascal/mikroBasic program on the host PIC microcontroller and view variable values, Special Function Registers (SFR), memory and EEPROM while the program is running.

On-board USB 2.0 PICFlash programmer – an ultra fast USB 2.0 programmer for MCU programming. Continuing its tradition as the fastest PIC programmer on the market, a new PICFlash with mikroICD now supports more PIC MCUs giving developer a wider choice of PIC MCU for further prototype development.

Package contains: EasyPIC4 development system, USB cable, Serial cable, User's manual, MikroICD manual, CD with software, drivers and examples in C, BASIC and Pascal language. Note: LCD, DS1820 temp sensor and GLCD are optional.

PICFlash

with mikroICD support

PICFlash programmer – an ultra fast USB 2.0 programmer for the PIC microcontrollers. Continuing its tradition as one of the fastest PIC programmer on the market, a new PICFlash with mikroICD now supports more PIC MCUs giving developer a wider choice of PIC MCU for further prototype development.

mikroICD debugger enables you to execute mikroC / mikroPascal / mikroBasic programs on the host PIC microcontroller and view variable values, Special Function Registers (SFR), memory and EEPROM while the program is running.

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mikroElektronika Compilers

Pascal, Basic and C Compilers for various microcontrollers

Supporting an impressive range of microcontrollers, an easy-to-use IDE, hundreds of ready-to-use functions and many integrated tools makes MikroElektronika compilers one of the best choices on the market today. Besides mikroICD, mikroElektronika compilers offer a statistical module, simulator, bitmap generator for graphic displays, 7-segment display conversion tool, ASCII table, HTML code export, communication tools for SD/MMC, UDP (Ethernet) and USB, EEPROM editor, programming mode management, etc.

Each compiler has many routines and examples such as EEPROM, FLASH and MMC, reading/writing SD and CF cards, writing character and graphics on LCDs, manipulation of push-buttons, 4x4 keyboard and PS/2 keyboard input, generation of signals and sounds, character string manipulation, mathematical calculations, I²C, SPI, RS232, CAN, USB, RS485 and OneWire communications, Manchester coding management, logical and numerical conversion, PWM signals, interrupts, etc. The CD-ROM contains many already-written and tested programs to use with our development boards.

mikroElektronika manufactures competitive development systems. We deliver our products across the globe and our satisfied customers are the best guarantee of our first-rate service. The company is an official consultant on the PIC microcontrollers and the third party partner of Microchip company. We are also an official consultant and third party partner of Cypress Semiconductors since 2002 and official consultant at Philips Electronics company as well.

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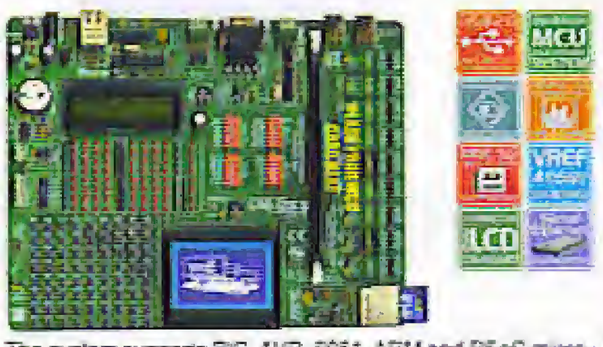
Uni-DS 3 Development Board

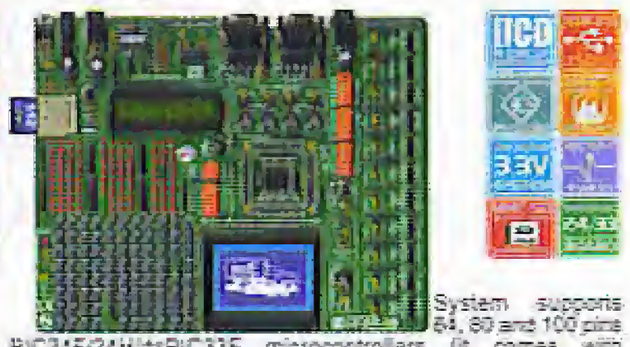
with on-board USB 2.0 programmer



The system supports PIC, AVR, 8051, ARM and PSoC microcontrollers with a large number of peripherals.In order to continue working with different chip in the same development environment, you just need to switch a card. **UNI-DS3** has many features that make your development easy. You can choose between USB or External Power supply. Each MCU card has its own USB 2.0 programmer!

LV24-33 Development Board

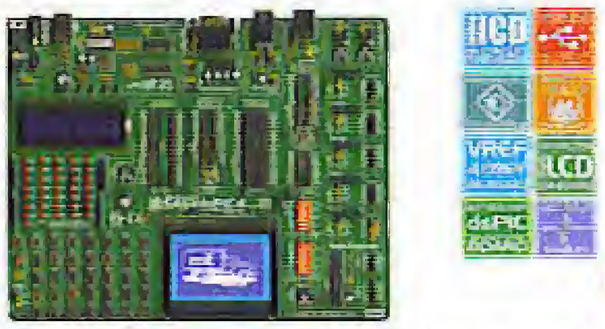
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD



System supports 64, 80 and 100 pins PIC24F/24H/dsPIC33F microcontrollers (it comes with PIC24FJ96GA010 - PIC24 16-bit Microcontroller, 96 KB Flash Memory, 8 KB RAM in 100 Pin Package). Examples in BASIC, PASCAL and C are included with(in) the system. You can choose between USB and External Power supply. **LV 24-33** has many features that make your development easy. Explore new PIC24F/24H/dsPIC33F PIC MCU's with LV 24-33 and experience all advantages of these microcontrollers.

EasydsPIC4 Development Board

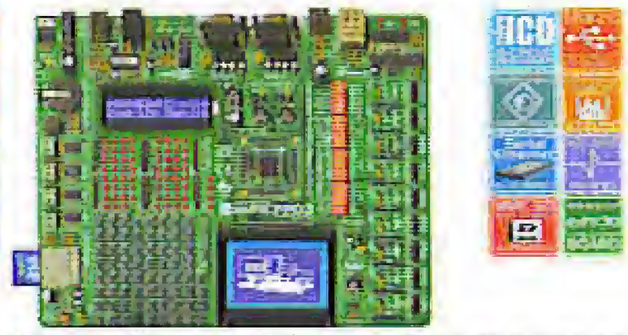
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD



The system supports 18, 28 and 40 pin microcontrollers (it comes with dsPIC30F4013 general purpose microcontroller with internal 12-bit ADC). **EasydsPIC4** has many features that make your development easy. Many of these already made examples in C, BASIC and PASCAL language guarantee successful use of the system. Ultra fast on-board programmer and **mikroICD** (In-circuit Debugger) enables very efficient debugging and faster prototype developing.

dsPICPRO 3 Development Board

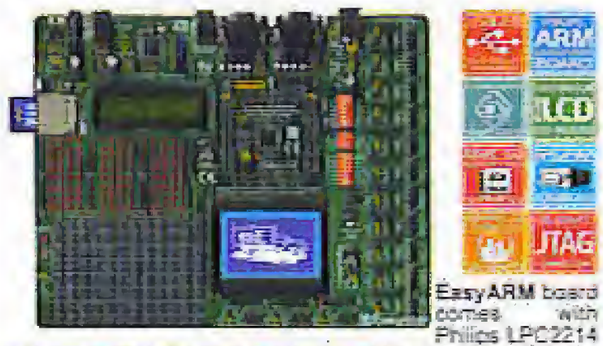
Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD



The system supports dsPIC microcontrollers in 64 and 80 pins packages. It is delivered with dsPIC30F6014A microcontroller. **dsPICPRO3** development system is a full-featured development board for the Microchip dsPIC MCU. dsPICPRO3 board allows microcontroller to be interfaced with external circuits and a broad range of peripheral devices. This development board has an on-board USB 2.0 programmer and integrated connectors for MMC/SD memory cards, 2 x RS232 port, RS485, CAN, on-board ENC28J60 Ethernet Controller, DAC etc...

EasyARM Development Board

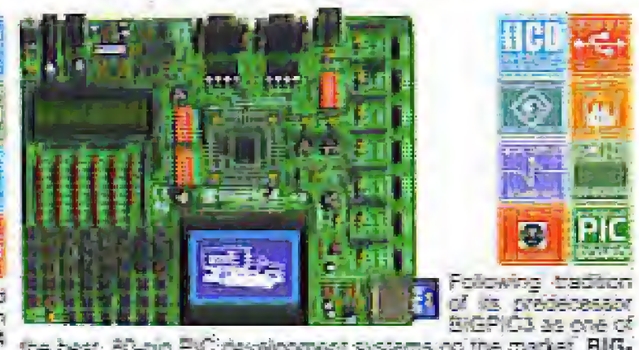
with on-board USB 2.0 programmer



EasyARM board comes with Philips LPC2214 microcontroller. Each jumper, element and pin is clearly marked on the board. It is possible to test most of industrial needs on the system: temperature controllers, counters, timers etc. EasyARM has many features making your development easy. One of them is on-board USB 2.0 programmer with automatic switch between 'run' and 'programming' mode. Examples in **C** language are provided with the board.

BIGPIC4 Development Board

Complete Hardware and Software solution with on-board USB 2.0 programmer and mikroICD



Following tradition of its predecessor BIGPIC3 as one of the best 80-pin PIC development systems on the market, **BIGPIC4** continues the tradition with more new features for the same price. System supports the latest (64) and 80-pin PIC microcontrollers (it is delivered with PIC18F6520). Many of these already made examples guarantee successful use of the system. Ultra fast on-board programmer and **mikroICD** (In-circuit Debugger) enables very efficient debugging and faster prototype developing. Examples in **C**, **BASIC** and **Pascal** language are provided with the board.

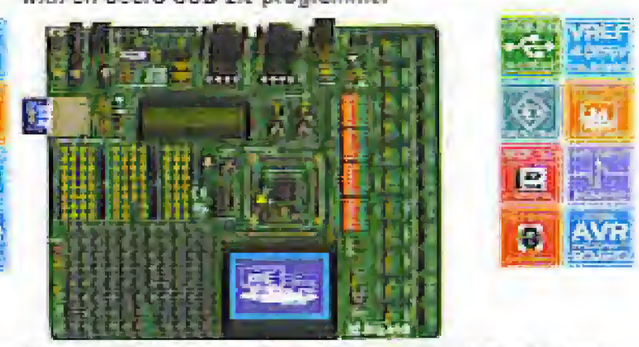
EasyAVR4 Development Board

with on-board USB 2.0 programmer

The system supports **8, 20, 28 and 40 pin** microcontrollers (it comes with ATMEGA16). Each jumper, element and pin is clearly marked on the board. It is possible to test most of industrial needs on the system: temperature controllers, counters, timers etc. **EasyAVR4** is an easy-to-use Atmel AVR development system. On-board USB 2.0 programmer makes your development easy. Examples in **BASIC** and **Pascal** language are provided with the board.

BIGAVR Development Board

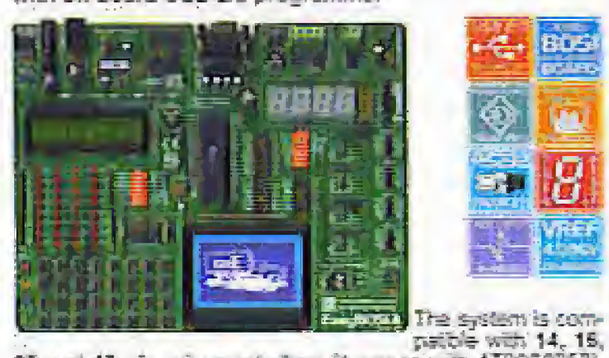
with on-board USB 2.0 programmer



The system supports 64-pin and 100-pin AVR microcontrollers (it is delivered with ATMEGA128 working at 16MHz). Many already made examples guarantee successful use of the system. **BIGAVR** is easy to use Atmel AVR development system. BIGAVR has many features that makes your development easy. You can choose between USB or External Power supply. BIGAVR also supports Character LCD as well as Graphic LCD.

Easy8051A Development Board

with on-board USB 2.0 programmer



The system is compatible with **14, 15, 20 and 40 pin** microcontrollers (it comes with AT89S8252). USB 2.0 programmer is built-in and programming can be done without removing the microcontroller. Many of industrial applications can be tested on the system : temperature controllers, counters etc.

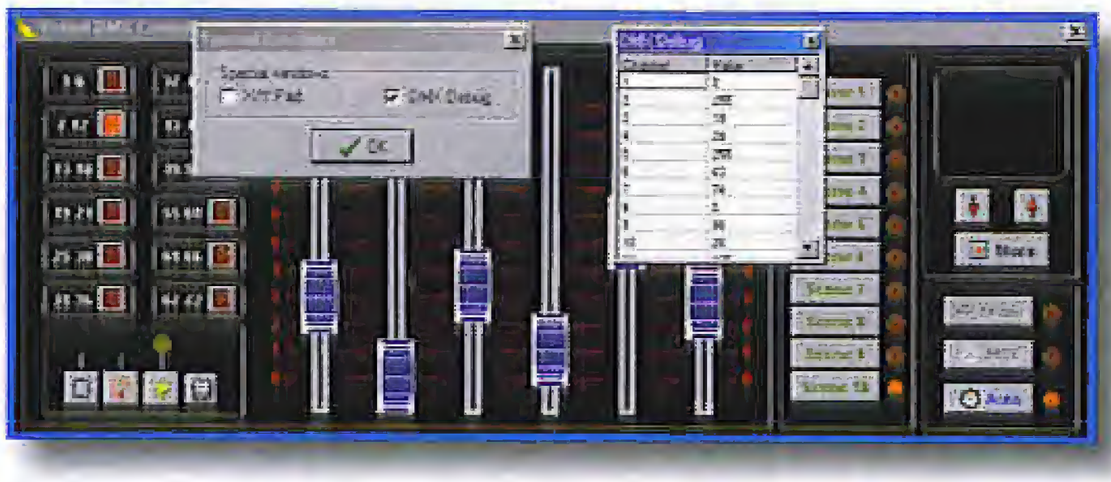
EasyPSoC3 Development Board

with on-board USB 2.0 programmer

The system supports **8, 20, 28 and 48 pin** microcontrollers (it comes with CY8C27643). Each jumper, element and pin is clearly marked on the board. **EasyPSoC3** is an easy-to-use PSoC development system. On-board USB 2.0 programmer provides fast and easy in-system programming.

Please visit our web page for more info http://www.mikroe.com

SOFTWARE AND HARDWARE SOLUTIONS FOR EMBEDDED WORLD



MIDI to DMX

Hi there — I have built your MIDI-DMX project (September 2001, *Ed.*) using a PCB purchased from yourselves. I have checked everything and the project does not seem to function.
4 meg and 24 meg clocks are present, there is activity on the data and address busses but no output from the UART.
Is it possible there were any errata in the documentation etc? Any ideas welcome.
Phill Macdonald (by email)

One of our prototypes was capricious when starting, giving erroneous UART operation. The only solution to get it to work properly was to add a push-button in parallel with capacitor C1 so we were able to reset the board manually, if necessary. Since fitting this button, the prototype has always worked correctly. Even if this phenomenon appeared on just one of our prototypes, we should mention this workaround. In the end we discovered that the BAUDOUT pin of IC6 was stuck at 66 Hz, when it should go to 4 MHz.
It is not clear from your message whether the supplied test program dmx_tester.exe works, nor if you programmed the EPROM yourself or purchased our ready-programmed device 010003-21.

AVR drives USB

A number of readers have expressed their curiosity about the source of the USB firmware employed by the author for the project (March 2007), under freeware license. The company and the product may be found on the internet at

www.obdev.at/products/avrusb/index.html

The freeware license is also the reason for the circuit diagram appearing in the article.

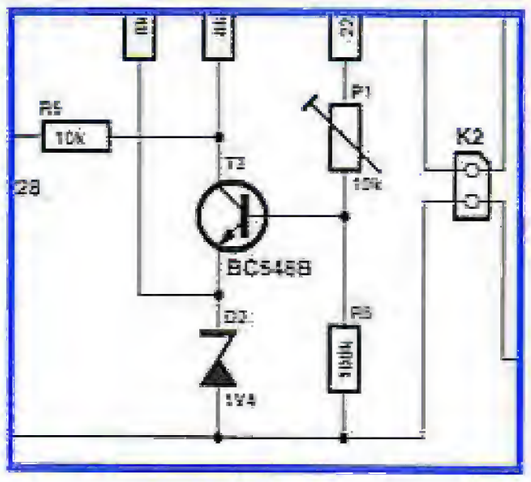
Shortwave Capture: forum buzzing and the optical encoder

A small community of radio enthusiasts has gathered around our latest shortwave receiver design (December 2006), and the participants' lively exchange of ideas in response to the publication may be read on our Forum under the header 'My circuit does not work (yet)'.
The rotary encoder used in the design was not specified in detail in the article. It is the type ECW1J-B24-AC0024 from Bourns. This device supplies 24 pulses per full revolution, enabling a step size of 24 kHz assuming a resolution of 1 kHz (which is sufficient for AM and FM tuning). For SSB listening in the ham radio bands, 100-Hz resolution will be selected resulting in 2.4 kHz tuning range per full turn of the encoder.
If a rotary encoder with a larger number of detents is used, it is even possible to achieve 100-Hz step tuning in all ranges. Suggested types include the ENC1J-D28-L00128L (128 detents) and ENC1J-D28-L00256 with 256 detents. Further information on these encoders at

www.bourns.com/components.aspx?cmsphid=76313831716329912829252#oe

1.4-volt zener diode

Dear Jan — I would like to point out that diode D2 is drawn incorrectly in the circuit diagram of the Simple Solar Charger from the April 2007 issue. The cathode of a diode is indicated by a coloured ring. Because zener diodes for low voltages are not operated in reverse-biased mode, the ring marker should be at the negative side of the circuit, i.e., the other way around than with zener diodes with a higher voltage.
Hans F. Kiefer (Germany)



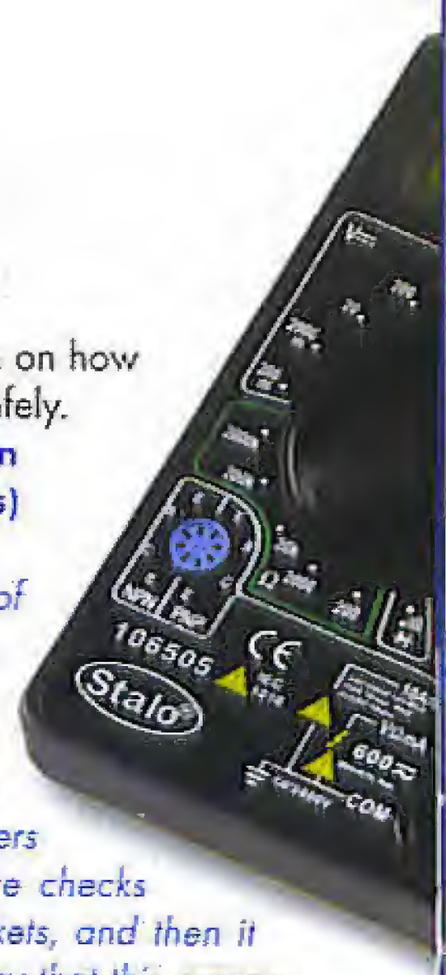
The very property you mention is discussed extensively in the text (did you read it?). None the less, the device is a zener diode and should be represented as shown in the circuit diagram.

£5 DMM from builders market

Dear Editor — I would like to respond to your article 'Accurate Measurements for a Fiver' I read in the February 2007 issue.

In the illustration I discovered the wording 'Cat II 600 V' which for all practical purposes means that a cheap meter like the one pictured can be used for checking 230-V mains voltage on a wall socket. Personally I would not like to have one of these in my hands for that purpose, if only for the risk of one of the test leads accidentally left in the 10 A receptacle (whatever IEC1010 has to say about about that!).

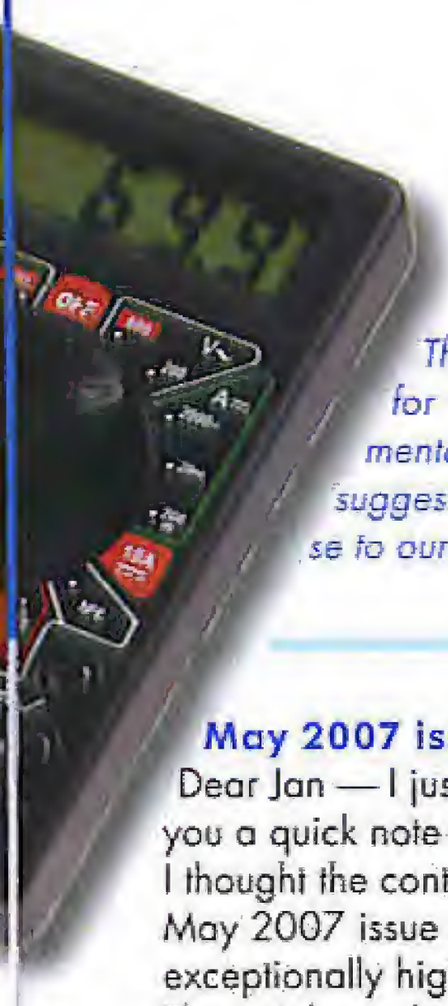
My point, really, is to say that the article is right in proving the usefulness of these cheap meters, but somewhat lacking in information on how to measure safely.
B. van Linden (Netherlands)



The author of the article, Fons Jansen, replies: "A typical use of these meters will be voltage checks on mains sockets, and then it is correct to say that this measurement should not be done with an unfused 10-A receptacle on the instrument, because otherwise the domestic fuses may blow. Consequently the user manual contains a number of safety guidelines to help prevent accidents.
However the gist of the article is the electronics inside these low cost meters, and the accuracy it can achieve. Although a section on safety would have been interesting, it was unfortunately outside the scope of the article. Nonetheless I hope you did like the article."

Scale Deposit Fighter — 'the green way'

Dear Jan — I was happy to see Mini Circuits appearing again in the March 2007 issue with a nice design of a water softener (Scale Deposit Fighter, *Ed.*). This type of circuit has been known for some time already and I have one installed on the main water intake pipe in my home. Whilst it serves it purpose quite well, I was less happy to reason that the device adds to my electricity bill, it being left on for 24 hours, 356 days a year. Although my proposed solution does consume a little power, I do steal it from a source that's humming anyway: the bell transformer. In this way I hope to do my bit for the environment, because there are losses anyway in the bell transformer. After all, if the water softener were to have its own transformer, there would be energy losses two times over. Just thought I'd send you this tip.
Malcolm Fabre (UK)

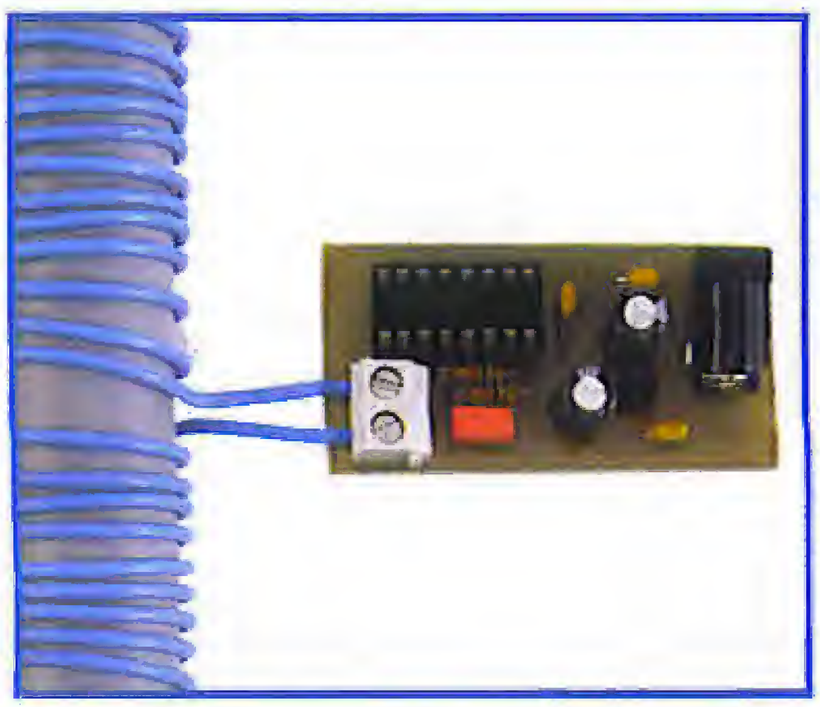


Thanks Malcolm for your environmentally inspired suggestion in response to our publication.

May 2007 issue

Dear Jan — I just had to drop you a quick note to say that I thought the content of your May 2007 issue was of an exceptionally high standard. The article on the LCD graphical display was very helpful and although I don't have any of the E-Blocks systems, I intend to now build my own PIC based interface using your module.
Then there was the article on the RDS radio beacon — a beautiful piece of software design and this was reflected in the almost trivial hardware. .... then the article on the Software Defined Radio. A truly amazing range! Your team must have burnt the midnight oil on that one.
Keep up the good work!
Mike Boyden (UK)

Thanks for the response Michael, it made a nice change from being at the wrong end of the customer complaints line.



Freescale samples

Dear Editor — I have wondered whether you could explain to me a matter that's related to your magazine's report on Freescale's offer of free samples ('Attack of the SpYder', March 2007 and 'g-Force on LEDs', April 2007, *Ed.*).
I have been unable to get these despite their web page confirming my request (via Farnell UK) which was around 6 weeks ago.
The authors of the article did not necessarily imply an arrangement with your magazine, but the implication was that they at least had obtained these themselves.
So I am wondering why I have not received any, or whether anyone else has. I am waiting to hear what Farnell have to say.
G.H. Davies (UK)

Information received from Freescale indicates that following the publication of our March 2007 issue many hundreds of readers have successfully obtained samples of the MC9S08 micro using the method printed in the article you refer to. See also the 'Freescale SpYder, CodeWarrior & Co' topic on our forum.
May we suggest you first obtain assistance, through a forum posting, from other readers on how they did it.
Samples should be ordered directly from Freescale, i.e. not through Farnell as you seem to have attempted.
If you still experience problems, let us know and I will assist.

Thank you for the explanation. I now realise that I clicked 'Farnell' on Freescale's web page thinking they would be supplying me, whereas it really named Farnell as the sample recipient! When I revisited the site I also ordered a $50 demoboard whereupon such ambiguity vanished. Sincerely, G.H.D.

Glad to see that the problems are sorted out. We should reiterate however that the supply of free samples of the MC9S08QG8CPBE chip is at the discretion of Freescale only, not Elektor or Farnell. The supply was set up as a special arrangement in support of the Elektor accelerometer and SpYder projects and may have been stopped when this edition is published (June 2007).

Solution to Hexadoku April 2007

6	0	A	C	D	8	2	E	9	1	4	5	3	F	7	B
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F	1	B	2	7	4	5	9	C	0	A	3	6	D	8	E
4	9	D	E	F	B	C	3	8	2	6	7	A	1	5	0
3	F	C	B	8	2	D	A	6	5	0	4	1	E	9	7
D	2	4	0	B	3	9	5	1	7	8	E	C	A	F	6
A	5	E	6	C	7	4	1	3	D	F	9	0	8	B	2
1	8	9	7	E	F	0	6	B	A	C	2	D	5	3	4
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5	E	2	A	4	D	1	7	F	C	3	B	8	0	6	9
9	7	6	3	0	E	8	2	5	4	1	A	B	C	D	F
C	B	0	4	6	9	A	F	2	8	E	D	5	7	1	3
2	A	8	F	1	0	7	B	D	3	9	C	4	6	E	5
0	4	7	9	5	6	3	8	A	E	B	1	F	2	C	D
B	6	1	5	9	C	E	D	4	F	2	0	7	3	A	8
E	C	3	D	2	A	F	4	7	6	5	8	9	B	0	1

Corrections & Updates

Wireless USB in miniature

March 2007, p. 44-51, ref. 050402-I

The battery must be disconnected from the prototyping board (Figure 10) if the circuit is powered by a mains adapter.

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Advertisement

Single-chip ZigBee® Platform in Package™ solution

Freescale Semiconductor has introduced a single-chip platform solution based on the ZigBee® specification that is designed to deliver the industry's lowest power consumption and highest performance. The MC1322x platform is engineered to support battery life of up to 20 years, doubling the expectations for current ZigBee solutions.

Freescale's MC1322x is available in a Platform in Package™ (PiP) solution that integrates the essential components of a ZigBee application within a single package, thereby reducing component count and system cost. The MC1322x platform contains a 32-bit microcontroller (MCU), a fully compliant IEEE® 802.15.4 transceiver, balun and RF matching components-all integrated into a small-footprint land-grid array (LGA) package that virtually eliminates the need for external RF components. The platform solution also features a TurboLink™ technology mode, engineered to increase data rates by up to 2 megabits per second between nodes.

Itron, a leader in advanced metering technology for the global utility industry, has selected the ZigBee standard for home energy management and load control applications for its OpenWay Advanced Metering Infrastructure (AMI) platform.

ZigBee technology currently targets industrial, commercial and medical applications, such as energy management and asset tracking. Freescale's proprietary TurboLink technology mode boosts the data rate up to 2 Mbps, providing an ideal platform to support diverse applications, such as voice, wireless headsets and compressed audio, as well as large data transfers. For healthcare-related applications, such as patient monitoring systems, TurboLink technology also enables real-time data collection from sensors on the body. That data then can be sent via a ZigBee network to a central location for monitoring.

The MC1322x devices will switch automatically between the IEEE 802.15.4 protocol and TurboLink technology packets, allowing the developer to take advantage of the high-speed capabilities, while simultaneously controlling and monitoring a ZigBee mesh network. This high-speed capability creates a tremendous opportunity for new designs and applications.

The MC1322x platform was designed from the ground up to support battery-powered applications. Optimized for Lithium-ion or NiCad batteries, the MC1322x is designed to support batteries as small as coin cells or use standard alkaline batteries that can provide up to 20 years of system life.

(070212-6)

www.freescale.com

MotionDSP launches new copyright detection technology

MotionDSP announced Ikena Copyright™, a copyright detection technology that matches content solely on the video content.

Ikena Copyright uses a (patent-pending) component of MotionDSP's military-grade video enhancement technology first announced in October, 2006. As opposed to audio-matching methods, MotionDSP's unique technology creates a 'video fingerprint' by tracking the motion characteristics the video.

Several major online video companies have already expressed strong interest in Ikena Copyright and MotionDSP expects several announcements in the coming months for agreements related to this technology platform.

Ikena Copyright is a pure video technology; it does not rely on audio fingerprinting in any fashion. It uses patent-pending video intelligence algorithms (which are based on MotionDSP's core video enhancement technology) to generate signatures for any video file.

Ikena Copyright's video signature system is claimed to stand up to many 'attacks' such as:

- Editing: it can identify clips as small as 20 seconds
- Low-bitrate compression: it can identify clips that have been re-encoded (i.e.: from their native format to Adobe® Flash® internet video)
- Aspect ratio change: 16:9 content compressed into a 4:3 display, or 4:3 stretched to 16:9
- Cropping the sides of a video
- Video quality change such as B&W conversion and colour distortion.

MotionDSP's core intellectual property is protected by several patents and is now being delivered to customers through its Ikena video processing service. Ikena is a scalable service for the automated processing and identification of video, designed for high-volume use by content owners such as Viacom®, Warner Brothers® and FOX®, as well as Internet Video sites such as MySpace™ and YouTube™. There is also great applicability for Ikena with mobile carriers such as AT&T®, Verizon® and DoCoMo®.

(070212-5)

www.motiondsp.com

New low-cost serial communications tool

Microchip announces the PICkit™ Serial Analyzer. This new tool enables design engineers to easily and cost-effectively interface with embedded circuits within serial systems using any Windows®-based PC.

The new PICkit Serial Analyzer comes complete with a 28-pin demo board featuring the 8-bit PIC16F886 microcontroller. The kit's hardware and Graphical User Interface (GUI) software allow testing and debugging of communication between the PC and several industry-standard serial protocols on the microcontroller being tested, including I2C™, SPI and USART.

Included are user's guides for the PICkit Serial Analyzer and the 28-pin demo board, complete source code, selected application notes, and Microchip's free MPLAB® IDE integrated development environment. The kit also comes with a GUI that enables designers to easily analyze the various serial communication protocols, as well as create and save scripts.

Available now, the PICkit Serial Analyzer (Part # DV164122) includes Microchip's 28-pin PIC16F886 Flash microcontroller demo board, USB cable and CD. The 28-pin demo board (Part # DM164120-3) can also be purchased separately and comes with one populated and two bare boards.

(070212-7)

www.microchipdirect.com

Single-cell Li-Ion / Li-Polymer chargers in SOT-23 packages

Microchip announces the cost-effective MCP7381X Li-Ion/Li-Polymer charge-management controllers. Offering programmable charge currents up to 500 mA, they feature integrated current sense, integrated pass transistor, thermal regulation and reverse battery protection, all in a 5-pin SOT-23 package.

Since they operate within USB output-power limits, the MCP7381X charge-management controllers can be powered via the USB ports on most PCs. The charge-enable input of the new devices provides a very simple interface for designers to use. The MCP73811 has a digital input and selectable USB charge currents of either 100 mA or 500 mA, while the MCP73812 offers a user-programmable charge current via an external resistor.

The new devices are ideal for a range of consumer electronic devices, such as rechargeable toys and low-cost MP3 players.

Samples of the new devices are available at sample.microchip.com and volume production orders can be placed today at www.microchipdirect.com. For more information, visit Microchip's Web site at:
www.microchip.com/MCP7381X.

(070321-1)

IR's New DirectFET® MOSFET Chipset Achieves Lowest On-State Resistance for 25V Applications

International Rectifier, IR® (NYSE: IRF), a world leader in power management technology, today introduced a new DirectFET® MOSFET chipset for high-current DC-DC converters used in notebook, high-end desktops and servers, and advanced telecom and datacom systems.

The IRF6712S control FET and IRF6716M sync FET are characterized with extremely low package inductance and device on-state resistance, gate charge and gate-to-drain charge to achieve high efficiency and superior thermal performance. They allow operation up to 25 amperes per phase, in a small, sleek form factor.

With low typical $R_{DS(on)}$ of only 1.2 mOhm at 10 V_{GS} and 2.0 mOhm at 4.5 V_{GS}, the IRF6716M MOSFET achieves the lowest on-state resistance for a 25 V device, making it well-suited to synchronous rectifier sockets for high-frequency, high-current DC-DC converters used in applications that power high-current loads. The IRF6716M features a slim 0.7 mm profile and the MX pad outline common to two generations of devices, allowing an easy migration from existing low-voltage DirectFET MOSFETs.

Optimized for high-current applications where a single control MOSFET is desired, the IRF6712S achieves a low gate charge (Q_g) of 13 nC and gate-to-drain charge (Q_{gd}) of 4.4 nC combined with low typical on-state resistance of 3.8 mOhm at 10VGS and 6.7 mOhm at 4.5 V_{GS}. The IRF6712S also presents a 0.7 mm profile and the SQ pad outline common to two generations of control devices, allowing an easy migration from existing low-voltage MOSFETS.

www.irf.com

(070321-4)

More 300V input mini modules

Vicor announces the addition of nine mid-power Mini DC-DC converters to its 300 Vdc input family: 100 W models at 2 and 3.3 Vout, 150 W models at 5, 12, 15, 24, 28, 36, and 48 Vout. The modules — which incorporate Vicor's patented low-noise Zero-Current and Zero-Voltage Switching (ZCS/ZVS) — can be used in a variety of applications, including off-line systems with autoranging front ends, industrial and process control, distributed power, medical, ATE, communications, defence, and aerospace. Low-noise ZCS/ZVS greatly reduces the design effort and filtering costs required for power converters to meet agency conducted emissions requirements.

The 300 Vin Mini family now comprises 17 models with output voltages spanning 2 to 48 Vdc and power levels from 100 to 250 W. The converters operate from 300 V nominal input, with an input range of 180 V to 375 V. Efficiencies range up to 89% for the higher output voltages. These models are available in five different environmental grades, with six different pin options and three baseplate options. They can also be configured in any combination using Vicor's PowerBench™ tools, which allow a customer to configure an infinite array of custom module designs on-line, and verify them in real time on Vicor's website.

The modules, which are optionally available as RoHS compliant, are a compact 57.9 x 55.9 x 12.7mm in size, with a height above board of just 10.9mm. They complement Vicor's already broad range of DC-DC converters, providing designers with additional cost-effective options to meet the needs of their applications.

www.vicorpower.com

(070321-3)

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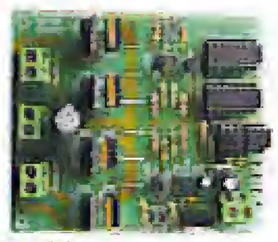
Motor Drivers/Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

NEW! PC / Standalone Unipolar Stepper Motor Driver

Drives any 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps max. Provides speed and direction control. Operates in stand-alone or PC-controlled mode. Up to six 3179 driver boards can be connected to a single parallel port. Supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£11.95**
Assembled Order Code: AS3179 - **£18.95**

NEW! Bi-Polar Stepper Motor Driver

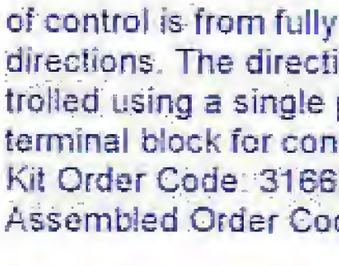


Drive any bi-polar stepper motor using externally supplied 5V levels for stepping and direction control. These usually come from software running on a computer. Supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - **£17.95**
Assembled Order Code: AS3158 - **£27.95**

NEW! Bidirectional DC Motor Controller

Controls the speed of most common DC motors (rated up to 16Vdc/5A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
Kit Order Code: 3166KT - **£16.95**
Assembled Order Code: AS3166 - **£25.95**

DC Motor Speed Controller (100V/7.5A)



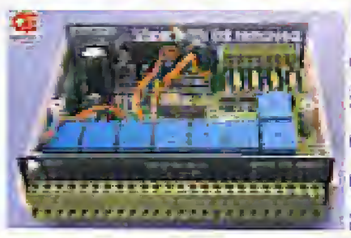
Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - **£13.95**
Assembled Order Code: AS3067 - **£21.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. Suitable PSU for all units: Order Code PSU445 £8.95

Serial Isolated I/O Relay Module



Computer controlled 8-channel relay board. 5A mains rated relay outputs. 4 isolated digital inputs. Useful in a variety of control and sensing applications. Controlled via serial port for programming (using our new Windows interface, terminal emulator or batch files). Includes plastic case 130x100x30mm. Power Supply: 12Vdc/500mA.
Kit Order Code: 3108KT - **£54.95**
Assembled Order Code: AS3108 - **£64.95**

Computer Temperature Data Logger

4-channel temperature logger for serial port. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 38x38mm. Powered by PC. Includes one DS1820 sensor and four header cables.
Kit Order Code: 3145KT - **£18.95**
Assembled Order Code: AS3145 - **£25.95**
Additional DS1820 Sensors - **£3.95 each**

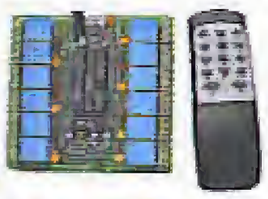
Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). *Two and Ten channel versions also available.*
Kit Order Code: 3180KT - **£44.95**
Assembled Order Code: AS3180 - **£51.95**

NEW! DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. Not BT approved. 130x110x30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£54.95**
Assembled Order Code: AS3140 - **£69.95**

Infrared RC Relay Board



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Met

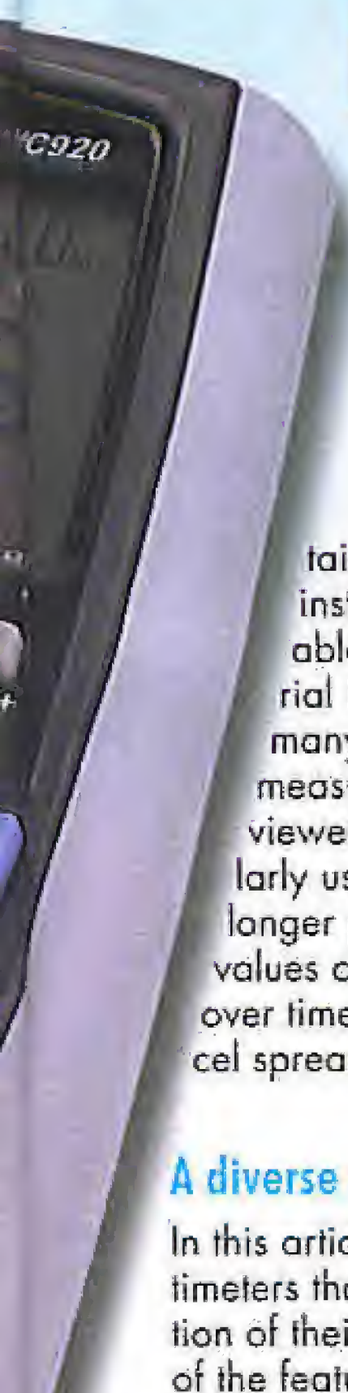
Harry Baggen

A multimeter is the standard measurement tool for every electronics hobbyist. You can use them to measure voltages, currents and resistances. Many modern multimeters can also measure capacitance and frequency. A few of them even have the facility of a PC connection for data logging. In this article we give an overview of (almost) all devices that are currently available with this feature.

Multimeters are the standard tools for every electronics engineer. Voltage, current and resistance can be easily measured with such an instrument. These devices are available in widely different price ranges, from a few pounds at some DIY stores up to hundreds of pounds for professional instruments. The type of multimeter chosen depends mostly on the application you want to use it for. If you only need to check an occasional fuse at home or measure a battery voltage then a cheap version will suffice. When voltages have to be measured at a higher accuracy, you'll need a totally different type of meter, preferably one that is calibrated. And for heavy duty service work yet another set of requirements applies.
In this article we won't look at multimeters within a cer-

ers with a tail

Portable multimeters with a serial interface



tain price range or with a certain accuracy, but instead we'll concentrate on (nearly) all the available multimeters with a certain feature, i.e. a serial interface. Such meters have been available for many years and they offer the facility to send the measured data via a cable to a PC where it can be viewed on screen or stored in a file. This is particularly useful for making automatic measurements over longer periods of time (data logging). The measured values can be shown in a graph to show the change over time, or processed further in, for example, an Excel spreadsheet.

A diverse crowd

In this article we'll give you an overview of the serial multimeters that are currently available, with a short description of their typical specifications as well as a description of the features offered by the accompanying software, because this information is often hard to find.
After extensive research we ended up with a list of about 20 meters that have a serial connection, of which some were not available in Europe or very difficult to get hold of. In the end we managed to obtain 15 meters for this overview in the Elektor Electronics lab, where we evaluated each one, along with the associated software.
The multimeters in this group are quite diverse. There are wide variations in price and specifications. The prices range from a few tens up to several hundred pounds, which makes it difficult to compare them all, so that's something we certainly won't attempt here.

Connecting to a PC

The connection between the multimeter and PC is usually implemented using a cable with a DB9 or USB plug on one end and a customised connector on the other end with one or two optical components (a transmitter LED and a receiver diode). This creates a good galvanic isolation between the multimeter and computer. With some devices there can be a connector where it isn't clear if a galvanic isolation is implemented. With the Digitek DT8000 for example, the meter did have a galvanically isolated connection even though the meter had a standard DB9 connector.
Most of the cheaper multimeters don't really have true communications capabilities, just a simple one-way link to the PC. The measurements are sent to the PC at regular intervals, but it's not possible for the PC to issue commands to the meter, for example to change a setting. With some meters this can be easily seen because the optical interface of the meter consists of only an LED. It's less obvious for other models, but you may find that the optical connector of the cable has just a receiver diode. For simple logging applications this isn't really a problem. The more expensive models always seem to offer true two-way communications and such a meter can be fully controlled via the PC software, which also gives access to setup menus where they exist.
Most of the meters come with an RS232 cable, but a number of them have a USB interface instead. Some of the models offer a choice of both versions. For hobbyists and firms with modern computers USB is a good choice, but for industrial applications RS232 is preferable. The communications speed isn't relevant here because the amount of data being sent is very small (at most a few measurements per second).
The Metrix MTX3283 is a super deluxe model that even includes a wireless capability via Bluetooth.

The software

Here too can we see clear differences between the cheaper and more expensive models. The software supplied by Digitek, Sinometer, Voltcraft, UNI and Velleman is fairly limited as far as the features are concerned. They're fine if you just want to follow the discharge curve of a lead-acid battery, for example. In any case, you'll always be able to see the measured value in a large font on the screen, which can be very useful under certain circumstances. Furthermore, the PC link is a nice extra feature, which the manufacturers exploit by showing an appealing simulated analogue scale on the screen.
There are a few notable features as well though. The software supplied with the Voltcraft VC-920 and the UNI UT70B (they look very similar) offers a few more features than the rest and can also store the measurements onto disc in several different formats. This is useful when you want to process the data at a later date in an Excel spreadsheet or a database-program. When a program uses the CSV format (comma separated values), you'll find that most other programs can import this format.
If you're after some extra features you can also use a separate software package that can be used with a few of the multimeters. In particular, DMM Profilab and Realview, both made by Abacom. You should of course first check that your type of meter is supported by these programs.

SERIAL MULTIMETERS

With the more expensive meters (Fluke, Agilent, Metrix, Gossen, Sanwa) it is clear that the manufacturers have paid more attention to the software and it is also better adapted to the available functions of the respective multimeters. With these versions you can set a logging period in advance, set the scale, whether the data should be averaged over a certain time, only start logging when a threshold value is reached, etc. Perhaps you will never need some of these functions, but for some (industrial) applications they come in very useful. There is more intelligence in the control of the meter via the PC and in some cases the meter can be completely controlled via the screen. This functionality comes at a price, but for professional use the higher cost will rarely be a problem.

The meters

The quality of the meter tends to determine the accuracy with which you can measure the voltages, currents, etc. This is usually reflected in the price. And do you need a calibrated instrument? ISO9001 certified companies have to use calibrated multimeters, so keep that in mind! Once you've acquired a calibrated meter you shouldn't assume that it will keep its accuracy forever. It will be necessary to have it recalibrated at regular intervals.
A multimeter isn't only used for measurements via a PC, but will often be used as a handheld device to make a few quick measurements. For this a sturdy device is the most suitable, and it should cope with a few knocks without affecting its accuracy. We mustn't forget the safety aspect either. The more expensive meters comply with Cat III/1000 V and Cat IV/600 V safety standards, whereas some of the cheaper models only comply with less stringent categories.
The choice here is clear: if you use a multimeter occasionally but don't want to miss the special measurement functions such as capacitance and frequency (plus of course the PC connectivity!), you'll find that the cheaper meters from our overview fit the bill perfectly. We particularly liked the Voltcraft VC-920 and UNI UT70B, which also came with good quality PC software.
At the more expensive end of the scale the choice becomes more difficult. All meters have their own unique specifications and advantages. In most cases the PC software has to be acquired separately, so keep that in mind when you work out the total cost. The Fluke 189, the Agilent U1252A, both the Sanwas, the Metrixes and the Gossens are all sturdy, accurate meters with extensive software. An honourable mention has to go to the Metrix MTX3283 because of its unique design, which we have never seen before in the multimeter world. Time will tell whether it is also practical in use, but at least the designers at Chauvin Arnoux (the manufacturer of the Metrix) certainly don't lack in creativity and courage!

In the following pages we give an overview of the meters along with the associated PC software.

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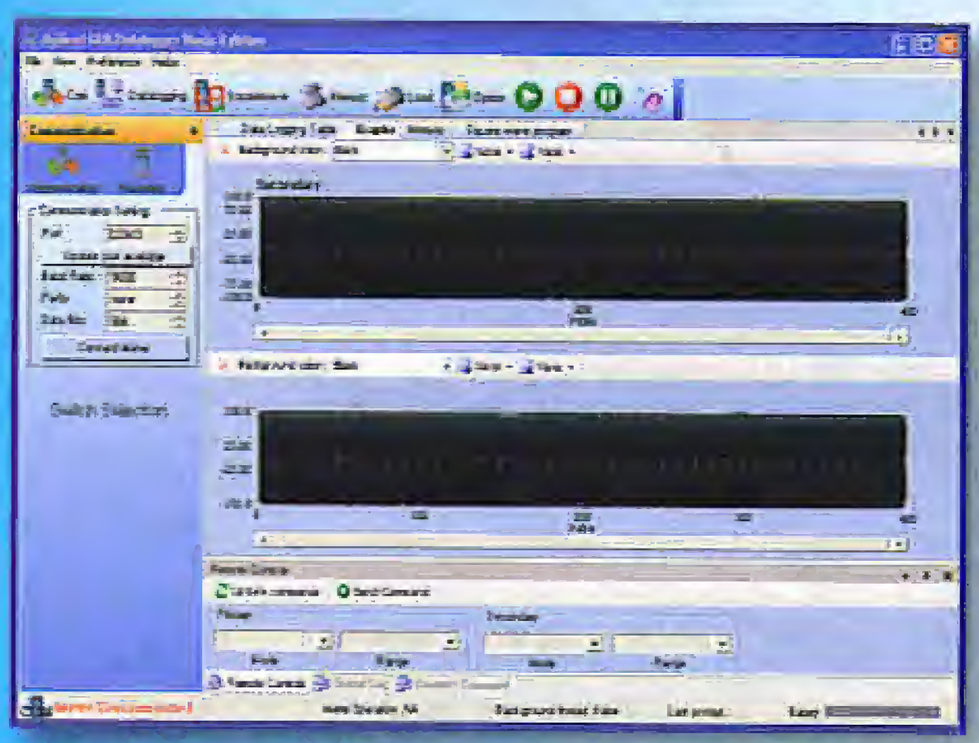
Agilent U1252A



Meter:
We know Agilent primarily for their larger measuring equipment, but they also have several handy multimeters in their range. The U1252A has a robust look and feel. The dual display (5 digits) has a bargraph and has a clear backlight. It has many measurement functions (such as capacitance, frequency, temperature), and also comes with a built-in squarewave generator with an adjustable duty-cycle. True RMS measurements up to 100 kHz and frequency measurements up to 100 MHz are possible. Standalone data logging is possible, with room in the internal memory for 200 measurements. There are many accessories available for this meter. A number of special settings are available via a setup mode.

Software:
The Basic Edition of the Agilent GUI Datalogger shows a clear display with on the left the meter settings and on the right a number of tabs. These can be selected to show a table of measurements, graphs, the contents of the internal memory of the meter and finally another tab for configuring the internal squarewave generator. For the logging you can set a date and time period, along with the interval and other settings. All measurements are stored in a CSV file with an automatically generated file name. The program stood out due to the many functions it had to control the meter.

Digitek DT-4000ZC

Meter:
This is a simple but handy multimeter in a removable rubber holster. The display has a resolution of 3 $^{3}/_{4}$ digits. This meter also has the facility to measure frequency and capacitance. There are separate push buttons for relative measurements, a hold function and for switching between frequency and duty-cycle. The connection to the PC is somewhat unusual, since it uses a 3.5 mm socket on the front of the meter. An optically isolated RS232 lead is supplied with the meter. An auto power-off function is built in, which can be disabled when lengthy measurements are made via the PC.

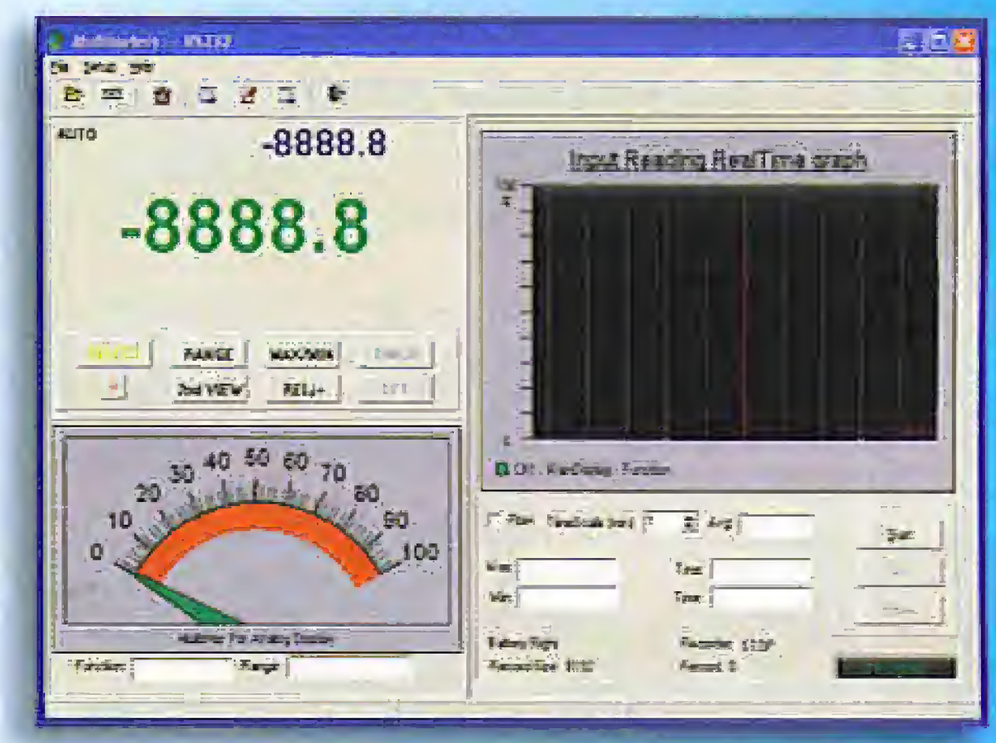
Software:
The supplied DMM program is a bit different compared to most others. The main window shows the present measurement in large digits, with an analogue scale with pointer underneath. A few buttons open up new windows with a table of recent measuremenis and a graph of the measurements over time. Unfortunately it is not possible to resize the windows.

The total logging time and sample interval are programmable. There are a few other settings, but they're rather limited. Data can be stored in a file using a comma separated text format.

Digitek DT8000

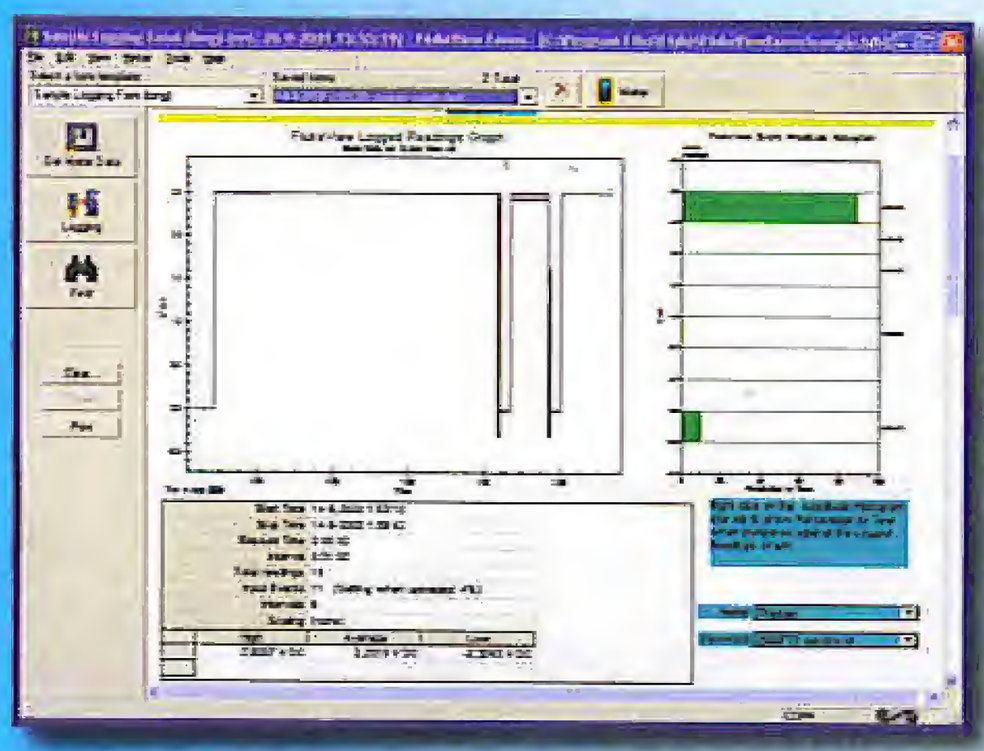
Meter:
The big brother of the DT4000 offers a better resolution (5 digits), a more comprehensive display (including the simultaneous display of two values for some ranges) and a few functions that aren't found in every meter. For example, it has a built in squarewave generator with a frequency up to 5 kHz and a programmable duty-cycle. Apart from buttons for Max/Min and Rel. there is also a timer button to give an alarm after a user-defined time. It is possible to set thresholds at which the meter gives an indication when the measurement goes over or under them. Despite the use of a standard DB9 connector on this meter, it is galvanically isolated from the PC via an internal optical coupling.

Software:
The supplied program is completely different to that supplied with the DT4000. The main window shows the two values that are also shown on the LCD of the meter. Underneath that is an analogue pointer and to the left you can see the measurements over time. There are many settings that can be changed in the program and most of the function buttons and settings of the meter are duplicated in the PC program (two way communications!). When a previously stored table with measurements is opened it appears in a separate window with a graphical representation underneath.



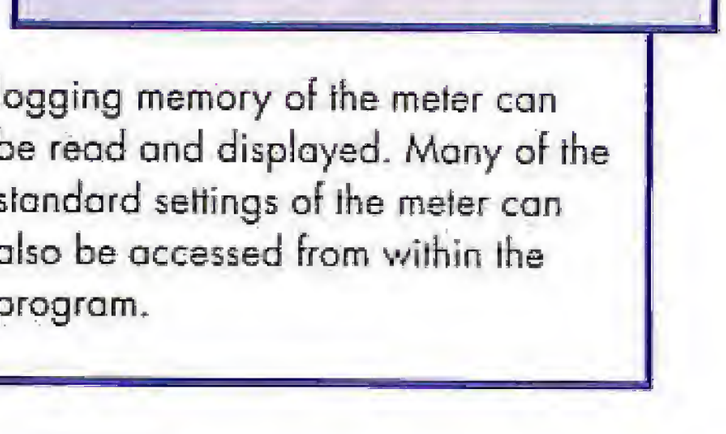
SERIAL MULTIMETERS

Fluke 189

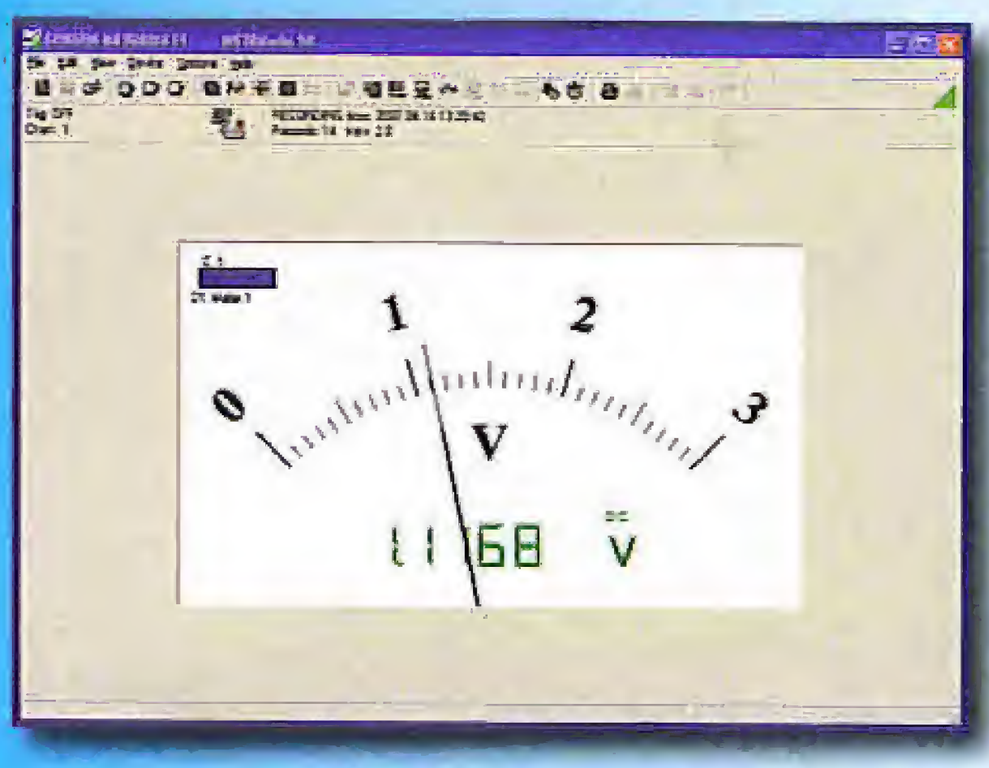


Meter:
This is a versatile multimeter in a sturdy, reliable housing. It has a very high standard accuracy of 0.025%. There is a clear 4 $^1/_2$-digit (5000) display with a separate bargraph. Apart from the standard ranges the meter also has the facility to measure dBm/dBV, Siemens, degrees Celsius and Fahrenheit. Frequency and capacitance are also covered. The AC ranges have a true RMS measurement up to 100 kHz. There are separate buttons for MIN/MAX/AVG, Hold, Relative and for selecting the rising or falling edge of the signal. Standalone logging is possible using the internal memory. There is a setup menu for the various settings.

Software:
The FlukeView Forms software has to be bought separately and is a comprehensive program that works with user definable 'forms'. The program has a large number of settings (e.g. for the start and stop times for logging, and for the percentage change of the signal that has to occur before an action is taken). It is also possible to show the measurements from two or three meters at the same time. The complete forms can be stored, but it is also possible to export just the data in CSV format. The internal logging memory of the meter can be read and displayed. Many of the standard settings of the meter can also be accessed from within the program.



Gossen Metrawatt Metrahit X-TRA



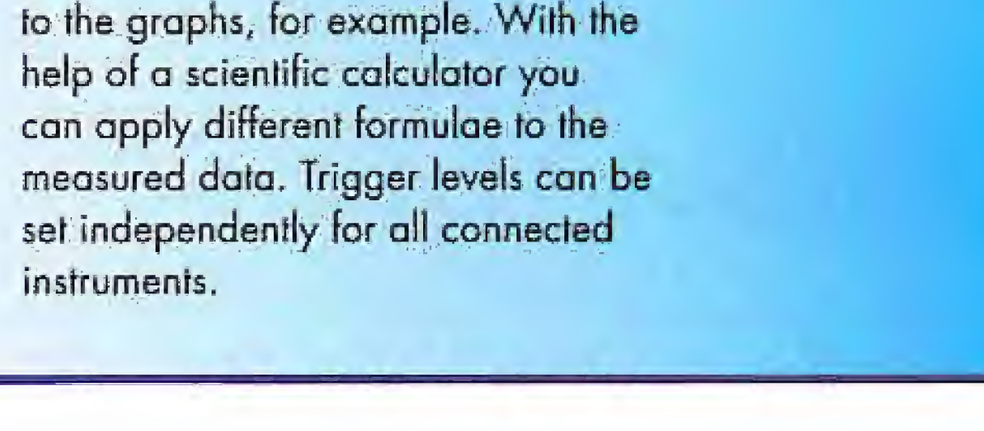
Meter:
This is a sturdy looking meter in a thick protective rubber holster. It has a 4 $^1/_2$-digit display with large digits and a bargraph. There are many measurement ranges, including frequency, temperature and capacitance. It offers true RMS measurements up to 20 kHz. There is a switchable low-pass filter for use when low-frequency AC signals have to be measured. The internal memory has a capacity of 15,400 measurements. It conforms to IP52 for protection against dust and water. Auto-ranging current measurements from 100 mA to 10 A can be made via a single connector. A unique Automatic Blocking System allows access to only the relevant connector for the selected range.

Software:
The associated software, Metrawin 10, is suitable for use with a maximum of 10 multimeters at the same time. The user can choose between a numerical display of the measurement (with bargraph), an analogue scale or as a graph (including a table with the values). There is only a limited number of combinations possible. Apart from a Y-t recorder it is also possible to display an X-Y recorder on the screen to generate Lissajous figures. There is a separate function for an FFT analysis of the measured signal. The measured data can be stored in several different formats. Many of the settings of the connected multimeter(s) can be changed from within the program. The internal memory of the multimeter can be read and displayed on the screen.

Gossen Metrawatt Metrahit 29S

Meter:
This model looks even sturdier than the Metrahit X-tra. It has a triple display and a wide range of settings, accessed via four function keys. It has a high-resolution display with $5\,^1/_3$ digits and a standard accuracy of 0.02%. It can also be used to make power readings and analyse mains power disturbances. The internal data logger memory has a capacity of 128 KB for storage of measurements. True RMS measurements can be made up to 100 kHz. Apart from the usual functions (such as V/A/Ω/f/C/T) it is also possible to measure W, VA, Var, Wh and VAh. The meter therefore comes with three test leads as standard! There is a built in frequency generator and a clock. This meter also includes the unique Automatic Blocking System of the input sockets.

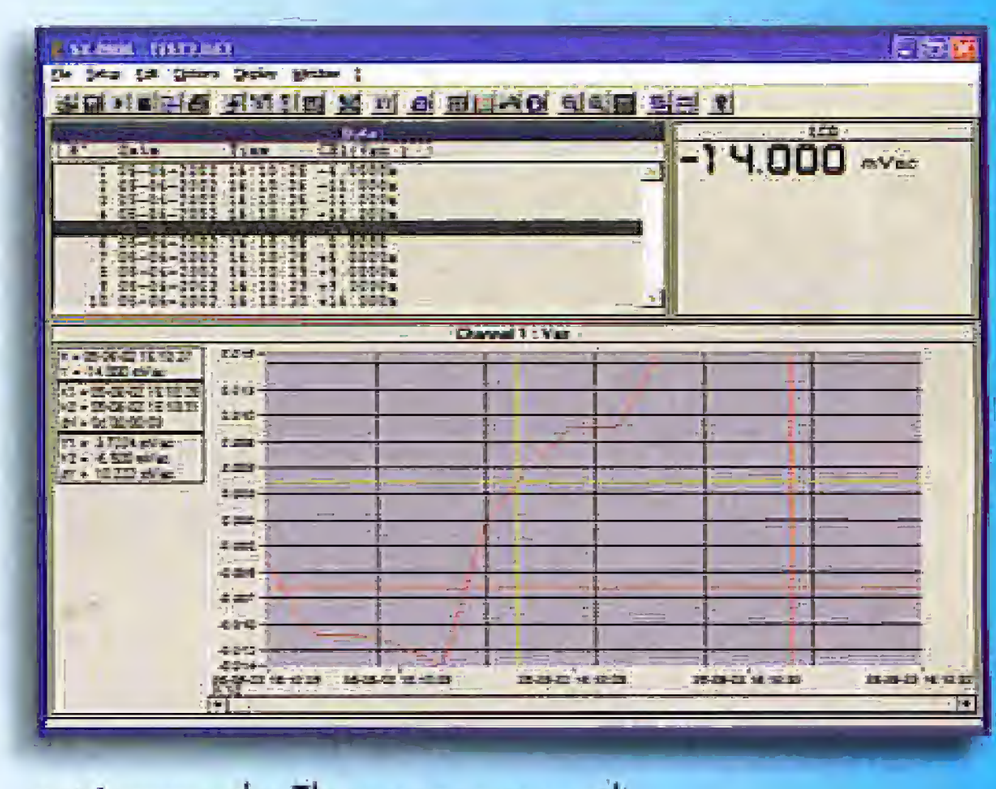
Software:
The Metrawin software is also used with this meter. For connecting the 29S to a PC a separate adapter is supplied that slides over the top of the meter. Just a few additional observations about the software: It has many different options for processing and printing the data. It is also possible to add your own comments to the graphs, for example. With the help of a scientific calculator you can apply different formulae to the measured data. Trigger levels can be set independently for all connected instruments.



Metrix MX26

Meter:
This is a well-designed, compact multimeter with a $3\,^3/_4$-digit display and bargraph, with a slighily unusual control method. Next to the backlight switch is a memory button that stores the currently displayed value into memory. The Peak button is used to store the value of short current or voltage spikes. Capacitance and frequency ranges are also present in this meter. The meter has a true RMS capability up to 100 kHz. It is noteworthy that the voltage input is on the left-hand side of the meter (on all other meters it is on the right). The battery compartment also offers access to the protection fuses for the current ranges.

Software:
The SX-DMM software from Metrix is a well-designed program with many functions. It doesn't show an analogue scale, just a table of the measurements along with the date and time they were taken. The measuring range can be selected using the software and the meter immediately returns a warning when the range is set incorrectly. There are many calculations that can be carried out on the measurements (various functions are available) and it is also possible to take several measurements at the same time (or add two different measurements together, for example). There is a separate option to export the data in Excel format.

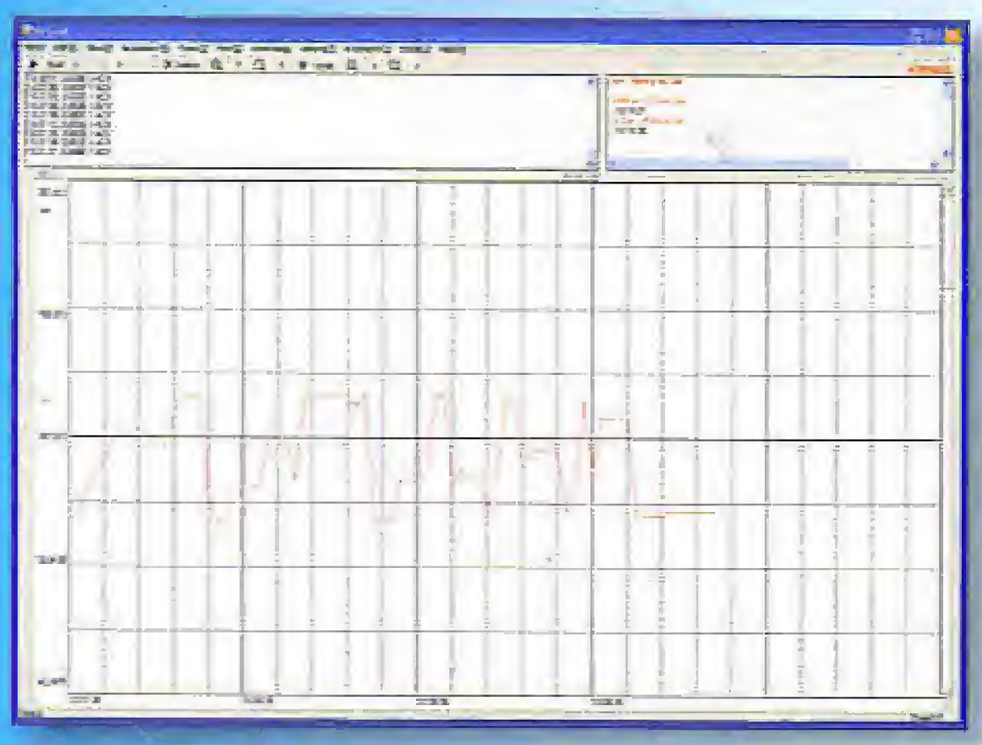


Metrix MTX3283

Meter:
This is the most extravagant meter that we got hold of. It looks very futuristic and has a hinged graphics display with several display options. The settings are controlled via a menu and it has a serial interface as well as Bluetooth. The meter has a 5 $^1/_2$-digit display, and the measurements can be shown in a graphical or numeric format. Up to four values plus the bargraph can be shown at the same time. It has all the standard ranges, including capacitance, frequency, temperature, and hold, peak and memory keys, and much more. The connections are at the back so that the leads won't be in the way when using the meter.

Software:
The SX-DMM software is the same as that supplied with the Metrix MX26. As we said earlier, this program offers many options for processing and storing the measurements and it's even possible to apply a formula to the measurements during the acquisition process. All meter settings can be changed from within the program. The program can also act as a web server, which makes it possible to view the measured data using any computer that is connected to the network.

Sanwa PC510



Meter:
This grey meter with a grey rubber protective cover isn't exactly eye-catching, but it still has a lot to offer. The calibrated instrument has a 3 $^3/_4$-digit display with large digits and a separate bargraph that reacts very quickly (60x/s according to the manual). This also has the usual ranges, including capacitance (up to 10 mF), frequency and temperature. There are separate buttons for Max/Min, Rel, Hold, Peak Hold and another button for zooming into the bargraph. True RMS measurements can be made up to 20 kHz. There are separate measurement ranges for 50 Ω and 50 mV DC.

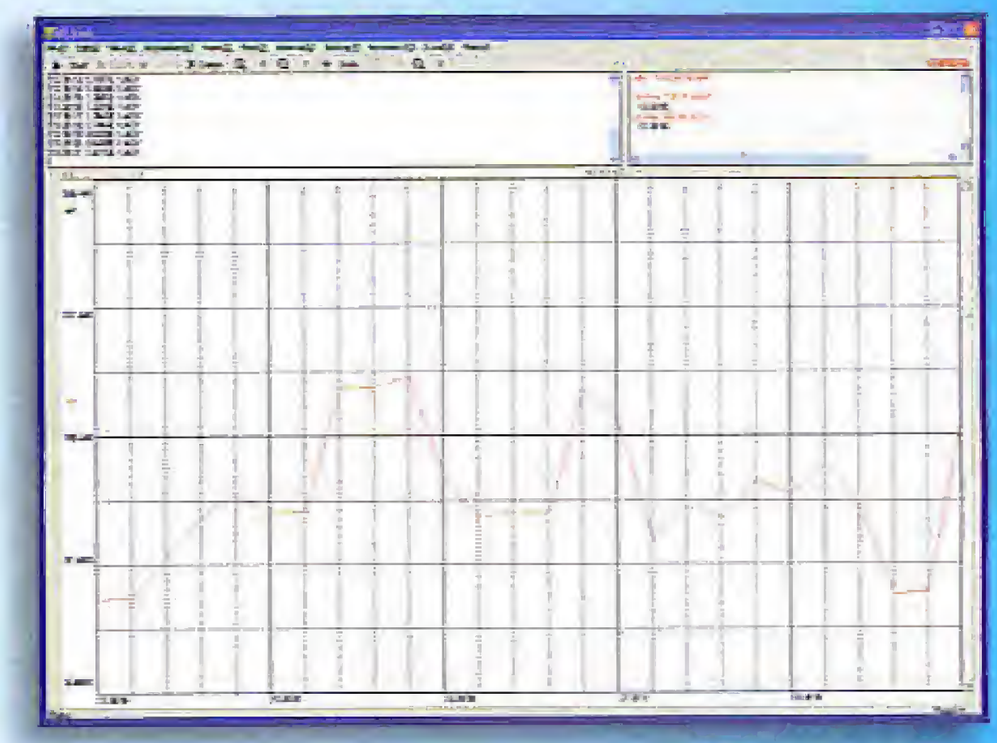
Software:
Sanwa offers a choice of two software-packages, PC Link and PC Link Plus. The latter is capable of logging measurements from a maximum of eight meters simultaneously. The program doesn't draw much attention to itself, just like the meter. We're presented with a large graph of the measured values with a table of the measurements above it and a sidebar for the settings to the right. Apart from the sampling interval you can also specify a date and start and end time for taking measurements, you can apply a linearisation table to the signal, upper and lower limits can be set and you can take relative measurements. Data can be exported in CSV format. The data can also be transferred directly into Excel.

Sanwa PC5000

Meter:
From the outside this device looks exactly the same as the PC510, with the same grey housing, the same dimensions and the same rubber cover.

The specifications are very much better though. Next to the identical bargraph we find a 5 $^{3}/_{4}$-digit display, which can be switched down to 4 $^{3}/_{4}$ digits via a button, which gives faster readings at DC voltages and frequency (5 x/s instead of 1.25 x/s). Here too we have true RMS measurements up to 20 kHz, capacitance and frequency, as well as extra sensitive ranges for resistance and DC voltages. Other functions are the measurement of current loops as used in serial connections, dBm measurements and duty-cycle measurements.

Software:
This model can be used with PC Link as well. The functions are identical to those described for the PC510. It was noticeable that the software reacted immediately when the meter was switched to a different function or resolution. Even when it was



switched from 4 $^{3}/_{4}$ to 5 $^{3}/_{4}$ digits the next measurement was always displayed in the correct format. The software can also be set up to forward the measured data once or at regular intervals to a previously configured address, or to send an email when a certain threshold value has been reached.

Sinometer MS8218

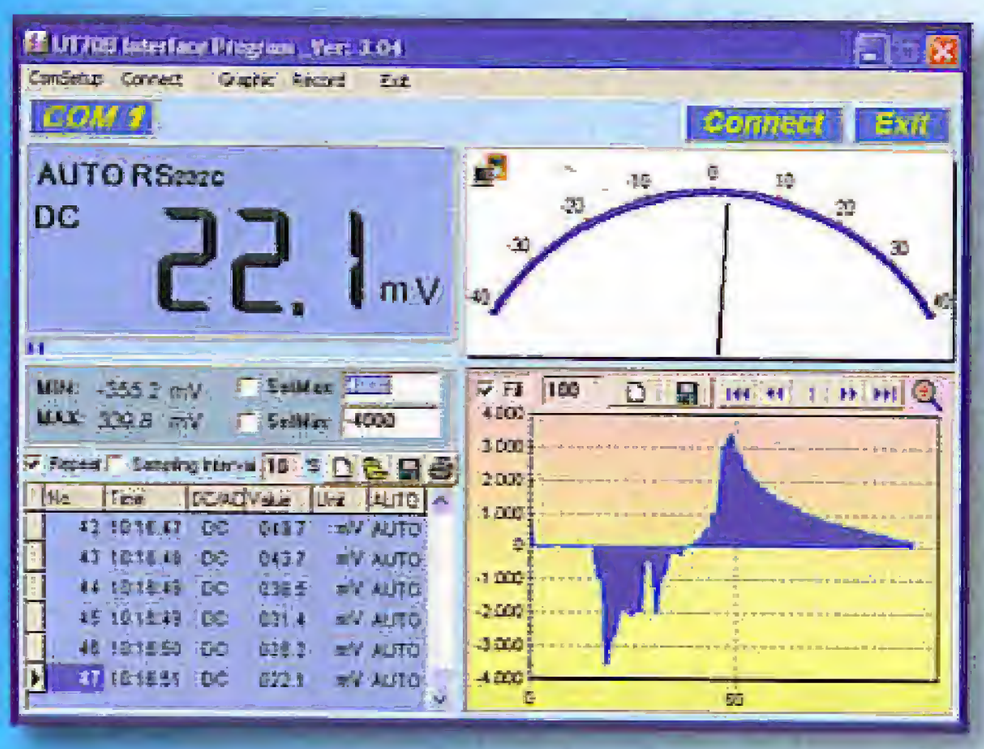
Meter:
This is a large meter with a dark green rubber holster. There is a 4 $^{3}/_{4}$-digits display with large digits, and a bargraph above it. The

standard accuracy is 0.03% and true RMS measurements can be taken up to 20 kHz. Apart from the standard functions there are also settings for capacitance and frequency (and duty-cycle) measurements. There is also a separate setting for dBm measurements. There are large buttons for Max/Min, Rel and Hold. It has a 15-minute auto power-off (which can be disabled) and a separate Wake button to turn the device back on again. The power supply is rather unusual in that it uses six AAA cells.

Software:
Most of the manufacturers implement the software in the same way. This is also the case here: an analogue and digital scale, a graph and a table with the measurements are all shown in one window. A nice touch is that the analogue display has a slight delay built in, simulating a real pointer. There are only a few settings and the sample interval can only be 0.5 or 5 seconds. This does make the software easy to use. The data is stored in CSV format. After opening a file, a new window appears with a clear overview of the measurements and a graph over time. Moving the cursor across the graph displays the actual value of the measurement at that point.

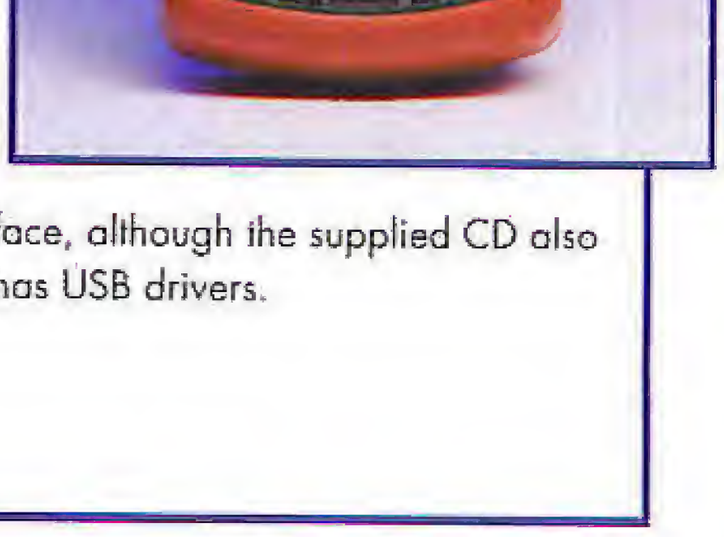
SERIAL MULTIMETERS

UNI-T UT70B

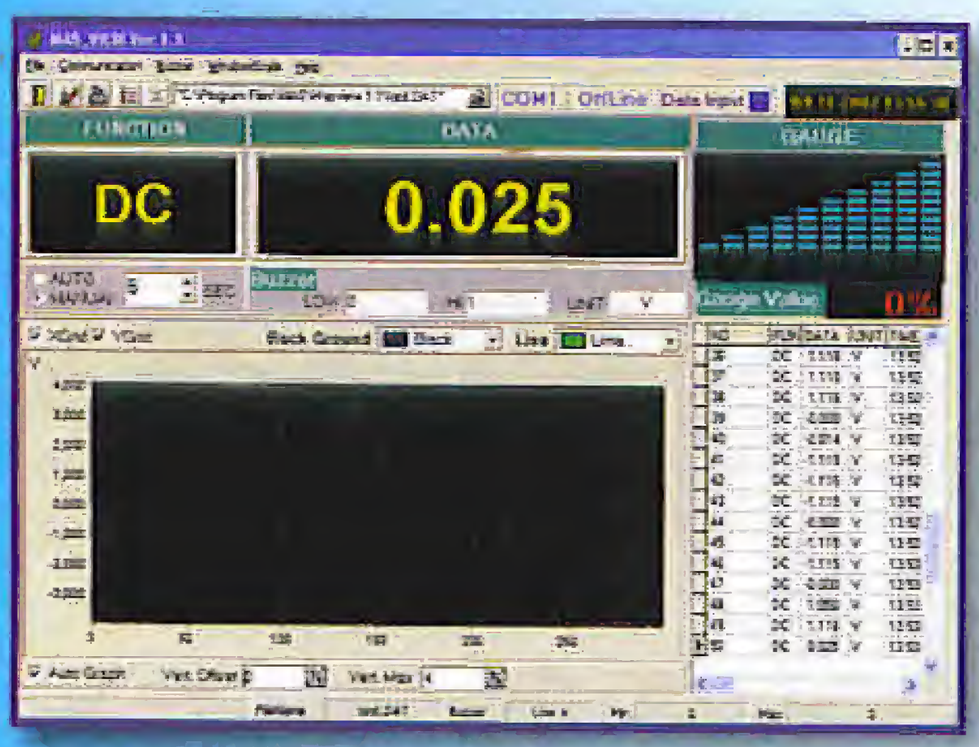


Meter:
This is a large, sturdy meter with a protective rubber holster. The 3 $^{3}/_{4}$-digit display is fairly large and easily readable, with a bargraph as well. The backlight can be independently turned on or off. The auto power-off-function turns off the device after 30 minutes. All the measurement capabilities of the other meters are found back here: apart from the standard functions there is also capacitance, frequency/RPM and separate ranges for degrees Celsius and Fahrenheit. There are separate buttons for Hold, Min/Max, Rel. and selecting the RS232 connection. The display reacts slightly sluggishly, but apart from that the meter is easy to use in practice.

Software:
The supplied software is almost identical to that for the Voltcraft VC-920 and it has the same functionality. Four windows are shown: the measured value in digits, an analogue meter scale, a column with the measured values and a graph. The number of measurements is configurable, as is the sample interval. Data can be stored in several different formats. This meter comes complete with an optical RS232 interface, although the supplied CD also has USB drivers.



Velleman DVM 345DI



(Identical to the MAS-345)

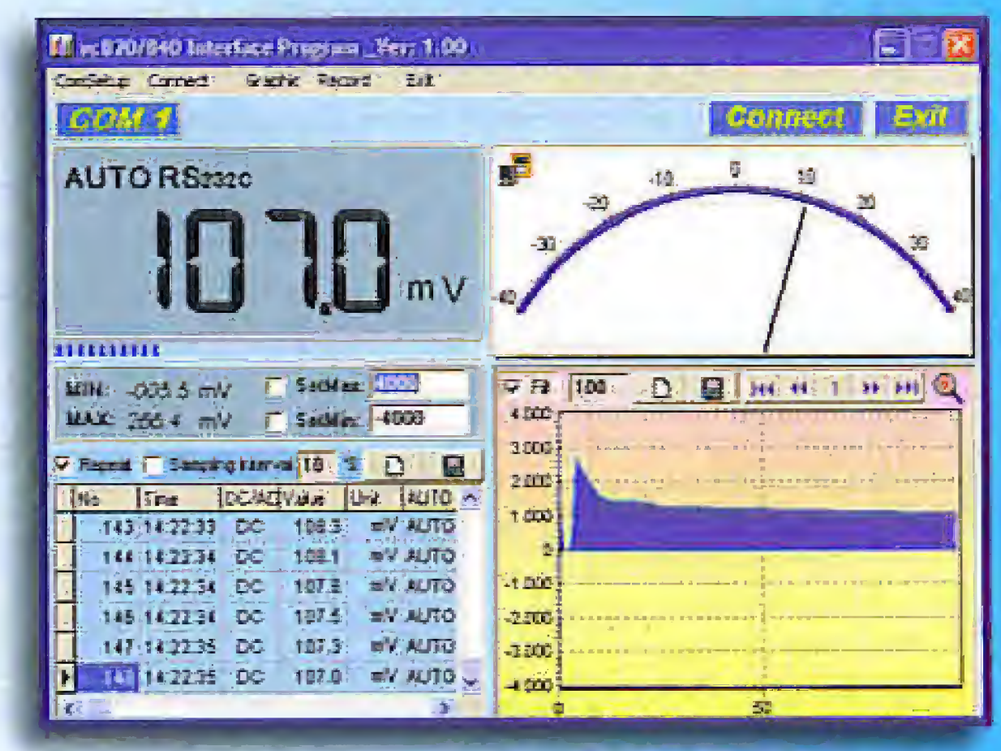
Meter:
This is a standard 3 $^{3}/_{4}$-digit meter with a removable soft plastic holster. The backlight can be switched on or off independently. There is also a bargraph below the digits. Apart from the usual functions, this meter also has a setting to measure the h_{fe} of transistors (via a small socket). There are two separate capacitance ranges and a temperature setting that uses the supplied temperature sensor. There is no auto power-off. There is an unusual RS232 connector with five long pins, and no mention is made of galvanic isolation.

Software:
The MAS-View program displays four windows: the DC/AC setting and next to it the measured value in numerical form, a bargraph with a percentage indication, a table with the measured values, and a graph of the measurements. Each window can be resized individually, the sampling interval can be modified and there is a buzzer function to sound an alarm when the measurement reaches a threshold. The data can only be stored in some sort of text format (.dat), and the file management in the program is rather difficult to use.

Voltcraft VC820

Meter:
This is a competitively priced meter with an easy-to-hold holster and a clear 3 $^{3}/_{4}$-digit display. Despite the low price all of the standard functions are included, also frequency and capacitance. There are separate buttons for selecting the range, duty-cycle, relative measurements and a hold function. The standard accuracy is 1%. Unfortunately it doesn't have an auto power-off facility. Apart from that it is a good basic meter, especially at this price.

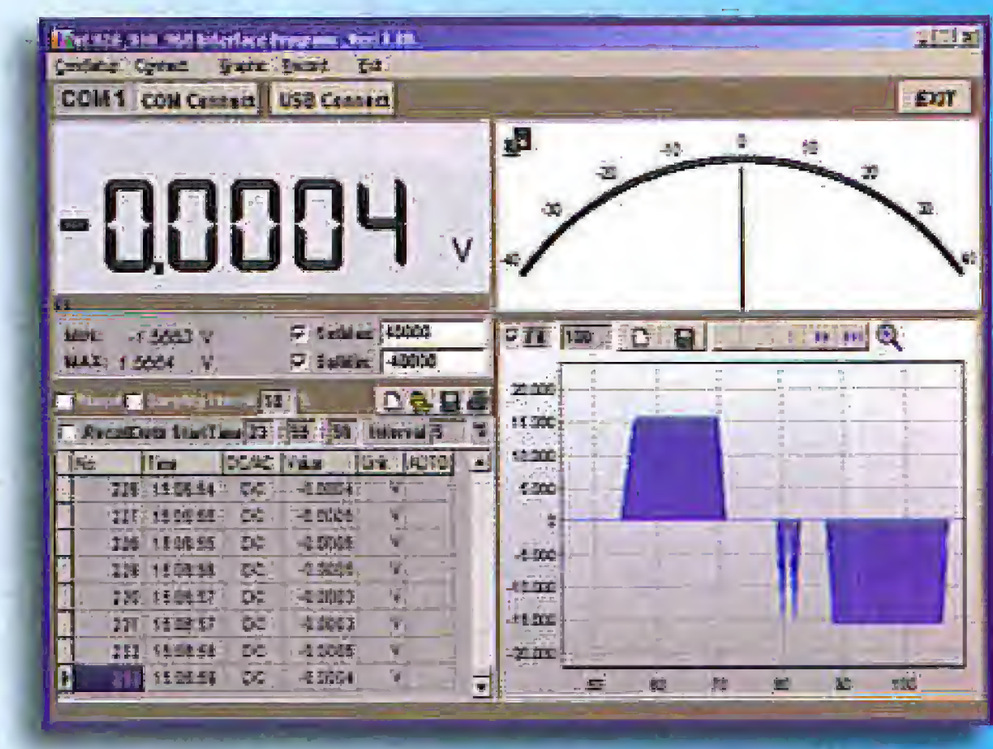
Software
The software looks similar to that for the VC920, but offers fewer functions. The connection to the PC is made with the supplied optical RS232 cable. The PC program is simple, and easy to use. The present measured value is shown on an analogue scale and in large digits. The measured values are also shown in a table and a graph. The time between samples can be set, but the meter keeps sending measurements at a rate of about one per second. The file management is somewhat restricted in this version in that the data can be stored in a file and retrieved again, but the file name is fixed.



Voltcraft VC920

Meter:
This is a sturdy meter with soft rubber edges. It has a large dual display with a bargraph, and a bright white backlight. It turns off automatically after an adjustable amount of time. The main display has 4 $^{3}/_{4}$ digits (40000). There are many different settings such as Min/Max display, Peak, Hold, Rel., storing and showing of a number of measurements, frequency (400 MHz) and capacitance (40 mF). It takes true RMS measurements up to 400 kHz. It is a well-designed device offering many functions.

Software:
The accompanying software is clear and easy to use. The window shows the actual value, an analogue meter scale, and the measured values in a table as well as a graph. It uses RS232 for the connection. USB is also possible, but you need to buy an optional cable for this. There is no help function.
You can measure a preset number of records or record indefinitely. The measured values can be stored in a file (Excel, database or text format) and can also be retrieved. The sampling interval can be set as a number of seconds and the graph can be scrolled and zoomed.



SERIAL MULTIMETERS

Brand & model	rrp (approx.) (£) excl. VAT	no. of digits [Hz]	basic accuracy [%]	C	f	AC (true-RMS)[1]	other ranges
Digitek DT-4000ZC	22 (€32)	3 3/4 (4,000)	0.5	100 µF	10 MHz	-	duty cycle
Voltcraft VC-820	27.50 (€40)	3 3/4 (4,000)	0.9	100 µF	10 MHz	-	-
Sinometer MAS-345	34 (€49)	3 3/4 (4,000)	0.5	400 nF	-	-	hfe
Velleman DVM345DI	43.50 (€63)	3 3/4 (4,000)	0.5	400 nF	-	-	hfe
Digitek DT8000	50 €73)	4 5/6 (80,000)	0.03	100 µF	8 MHz	-	rev count, dBm
UNI-T UT70B	50 (€73)	3 3/4 (4,000)	0.8	40 mF	400 MHz	-	rev count
Voltcraft VC-920	72.50 (€105)	4 3/4 (40,000)	0.1	40 mF	400 MHz	400 kHz	duty cycle; RS232
Sinometer MS8218	125 (€181)	4 5/6 (50,000)	0.03	5 mF	2 MHz	20 kHz	duty cycle; dBm
Sanwa PC510	146 (€212)	3 5/6 (5,000)	0.06	1 mF	125 kHz	20 kHz	-
Metrix MX 26	163.50 (€237)	4 5/6 (50,000)	0.3	50 mF	500 kHz	100 kHz	
Sanwa PC5000	242 (€351)	5 5/6 (500,000)	0.03	1 mF	2 MHz	20 kHz	duty cycle; dBm; RS232
Gossen Metrawatt Metrahit x-tra	310 (€449)	4 1/2 (12,000)	0.05	1 mF	1 MHz	20 kHz	pulsewidth
Agilent U1252A	310 (€450)	4 5/6 (50,000)	0.025	100 mF	20 MHz	100 kHz	pulsewidth; dBm; dBV
Fluke 189	351 (€509)	4 5/6 (50,000)	0.025	50 mF	1 MHz	100 kHz	pulsewidth; dBV
Gossen Metrawatt 29S	440.50 (€639)	5 1/3 (310,000)	0.02	30 mF	300 MHz	100 kHz	dB;W;VA;Var;Wh;Wah
Metrix MTX 3283 Bluet.	462 (€670)	5 1/2 (100,000)	0.02		2 MHz	200 kHz	dB; pulsewidth

[1] *Les valeurs ne sont pas comparables d'un appareil à l'autre en raison des différentes précisions données par chacun des fabricants.*

Brand & model	display backlight	auto-off	extra functions M=Min/Max, A=Average, H=Hold, P=Peak, R=Rel.	cable	software	rrp £ (€) excl. VAT [2]
Digitek DT-4000ZC	-	•	H, R	RS232	incl.	-
Voltcraft VC-820	-	-	H, R	RS232	incl.	-
Sinometer MAS-345	•	-	-	RS232	incl.	-
Velleman DVM345DI	•	-	-	RS232	incl.	-
Digitek DT8000	-	-	P, H, R	RS232	incl.	-
UNI-T UT70B	•	•	M, H, R,	RS232	incl.	-
Voltcraft VC-920	•	•	M, H, P, R	RS232	incl.	-
Sinometer MS8218	•	•	M, H, R	RS232	incl.	-
Sanwa PC510	-	•	M, H, P, R, Zoom	RS232	PC-Link	76 (€110)
Metrix MX 26	•	•	P, Mem	RS232	SX-DMM	103.50 (€150)
Sanwa PC5000	-	•	M, H, P, R	RS232	PC-Link	76 (€110)
Gossen Metrawatt Metrahit x-tra	•	•	M, H, square wave gen., data memory	USB	MetraWin	131 (€190)
Agilent U1252A	•	•	M, H, P, R, square wave gen., data memory	USB	incl.	-
Fluke 189	•	•	M, A, H, P, R, data memory	USB	FlukeView Forms	121 (€175)
Gossen Metrawatt 295	•	•	M, H, square wave gen., data memory, stopwatch	USB	MetraWin	131 (€190)
Metrix MTX 3283 Bluet.	•	•	M, H, P, R, data memory	USB	SX-DMM	103.50 (€150)

[2] *Logiciel y compris câble*

Manufacturer	Model	Manufacturer's internet address
Agilent	U1252A	www.agilent.com
Digitek Sinometer Uni	DT-4000ZC, DT8000 MAS-345, MS8218 UT70B	www.elv.de
Fluke	189	www.fluke.com
Gossen Metrawatt	28S, Metrahit x-tra	www.gossenmetrawatt.com/default.htm
Metrix	MX 26, MTX 3283	www.chauvin-arnoux.fr
Sanwa	PC510, PC5000	www.sanwa-meter.co.jp
Velleman	DVM345DI	www.velleman.be
Voltcraft	VC-820, VC-920	www1.uk.conrad.com

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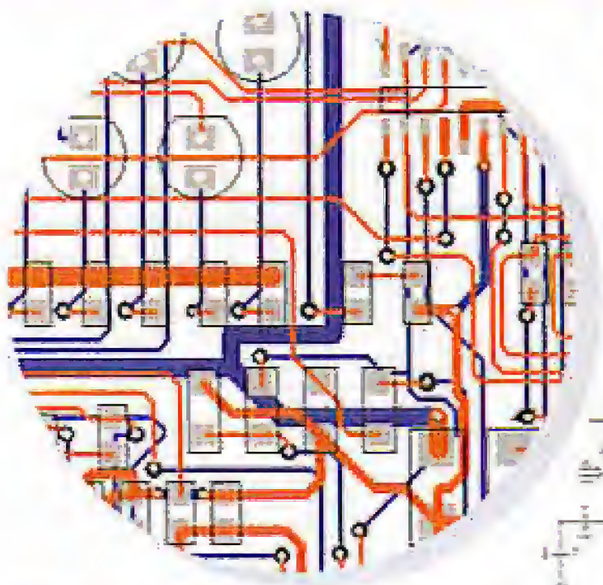

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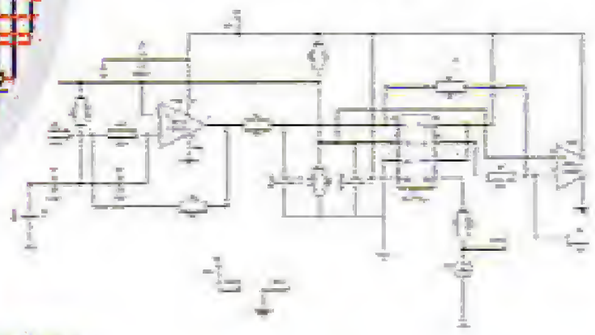

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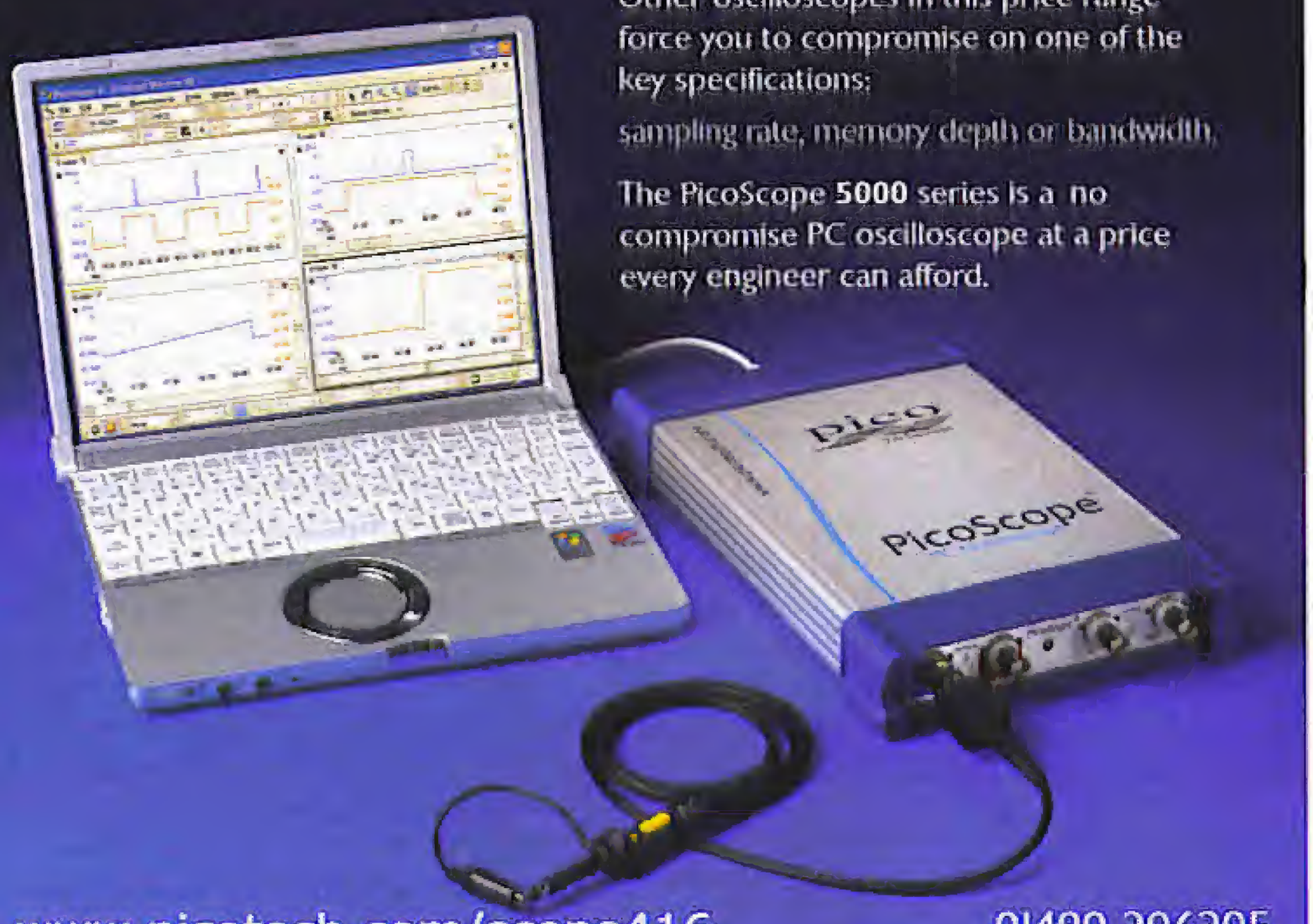

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2.4 GHz WiFi Spectrum

What's happening in your area?

Jason Hecker

This project takes advantage of certain parts of the circuitry in a 2.4GHz digital radio chip to make a simple spectrum analyser. This can give you a picture of which parts of the 2.4 GHz WiFi spectrum are being used in your immediate vicinity and even be used as an aid in optimising channel use and detection of interfering devices.

The 2.4-GHz Industrial, Science and Medical (ISM) band has been a boon for the short-range personal communications market in recent years. Due to its unlicensed nature and universal allocation, all sorts of communications devices for the home and office have become available. These include the ubiquitous 'WiFi' wireless LAN technology, digital cordless phones, video and audio transmitters, wireless keyboards and mice and Bluetooth among others. 'Unlicensed' does not mean anyone can just build his/her own transmitter and start using it — compliance rules exist in respect of maximum transmitter output power, bandwidth, fixed antenna construction and other aspects, and must be met before commercial 2.4 GHz units are allowed on to the market. Type approval for any 2.4 GHz transmitter equipment has to be obtained from relevant national institutions like FCC.

Heart of the project

The chip we're going to use is the CYWUSB6935 from Cypress Semiconductors, a complete two-way digital radio modem requiring few external components to operate. A similar device, the CYWUSB6934, was discussed in some detail in Ref. [1].

The datasheets of the '6935 device and the module may be found at [2] and [3] respectively. As you can see from the simplified block diagram in **Figure 1**, the '6935 contains a modulator, programmable frequency reference, demodulator, and most importantly for this project a Received Signal Strength Indicator (RSSI). It is through the combination of the programmable frequency generator and RSSI that a basic spectrum analyser can be constructed. By incrementing the frequency of the signal generator and reading the RSSI register shortly after, a useful picture of the 2.4-GHz band can be built up showing the relative levels of activity in this ISM band.

The chip itself is constructed in a QFN package. This is a surface-mount package that doesn't lend itself to soldering with a regular soldering iron. Fortunately Cypress has made available a module which can be utilised by mere soldering iron wielding mortals for useful projects. This module contains the chip, small antennas and the handful of components needed to support it. All the experimenter has to provide is

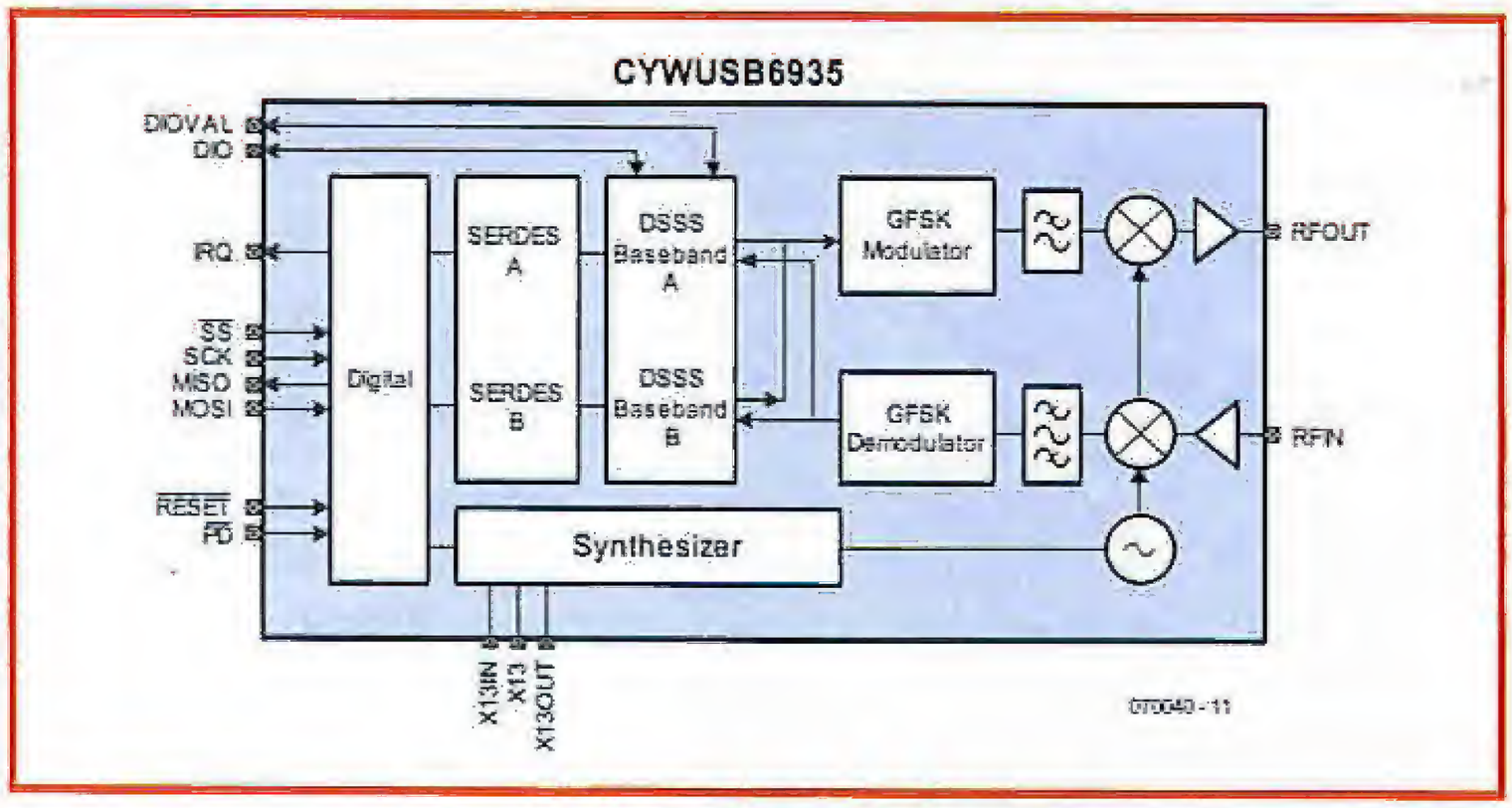


Figure 1. Block diagram of the CYWUSBB6935 WiFi data transceiver from Cypress.

Analyser

some power and a few digital signals to communicate with the chip.
"Lest we forget", samples of the CY-WUSB6935 may be obtained from Cypress.

Interfacing

The chip's internal registers can be read from and written to using the simple SPI protocol. Being a 3-volt CMOS part, this means that with suitable level conversion it can be connected to a microcontroller or a TTL parallel port. This project takes advantage of the parallel port (due to its simplicity and ubiquity) found on most PCs and laptops but the ideas demonstrated here can just as easily be applied to a microcontroller connected directly to the part.
Due to the 3 V (or more precisely, 2.7 V to 3.6 V) power, digital interfacing requirements of the chip are straightforward, hence a surprisingly simple circuit diagram can be drawn for the spectrum analyser— see **Figure 2**.
There are a couple of options for powering the chip itself. The parallel port cannot supply enough current to run the chip whereas the USB port has ample current sourcing ability. Two silicon diodes in series can drop the USB power from 5 V to about 3.6 V. Three diodes will drop it down to 2.9 V – both choices are fine for the operation of the chip. Bear in mind that PC power supplies can operate the 5 V power bus as low as 4.7 V (lower for the cheap or overloaded PSUs) so two diodes may be sufficient. The more expensive alternative is to use a 5 V to 3.3 V linear voltage regulator. A bench power supply may also be used if a USB port isn't available.

The TTL interface on a PC's parallel port can be easily used to connect to the 3 V CMOS-based SPI port. The digital output voltage from the parallel port can be reduced to compatible levels by simple voltage division. The signal input to the parallel port is a direct connection, as TTL will acknowledge V_H (logic High level) down to 2.4 V. The output from the TTL port can be as high as 5 V and as low as 2.4 V. In the author's experience, the High level output from the parallel port has been above 4 V so a di-

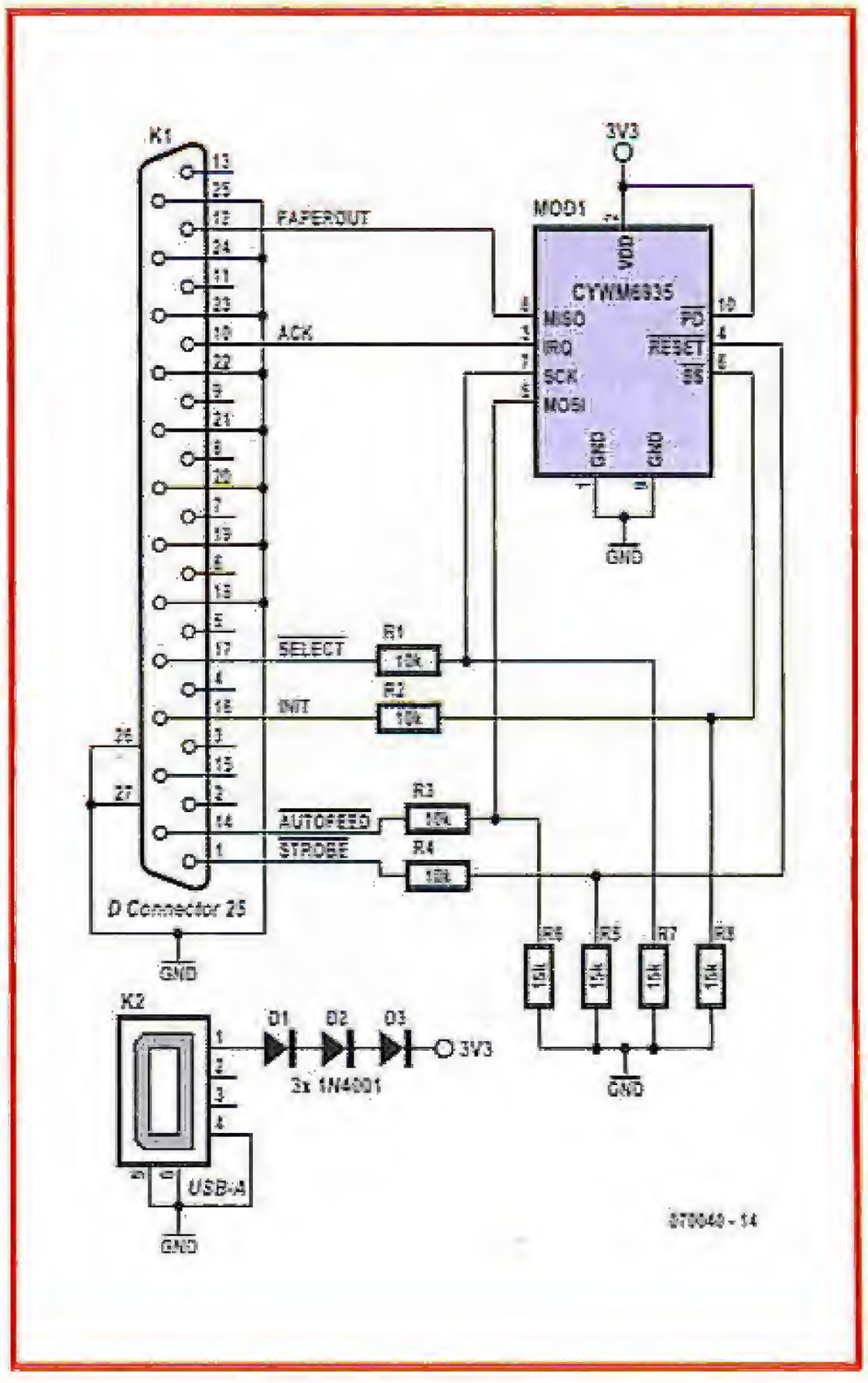


Figure 2. Circuit diagram of the spectrum analyser for the 2.4 GHz WiFi band based on the Cypress CYWUSB6935. USB connectivity is for supply purposes only!

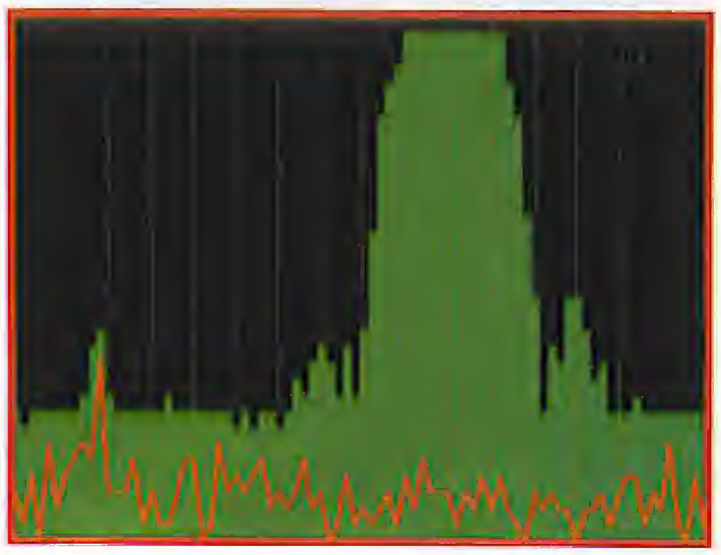


Figure 3a. 802.11b WLAN activity on channel 9.

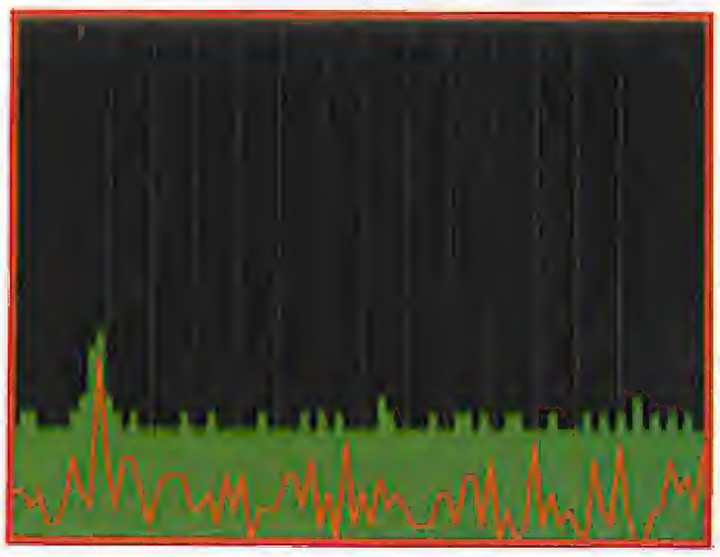


Figure 3b. Local source, probably a CPU clock.

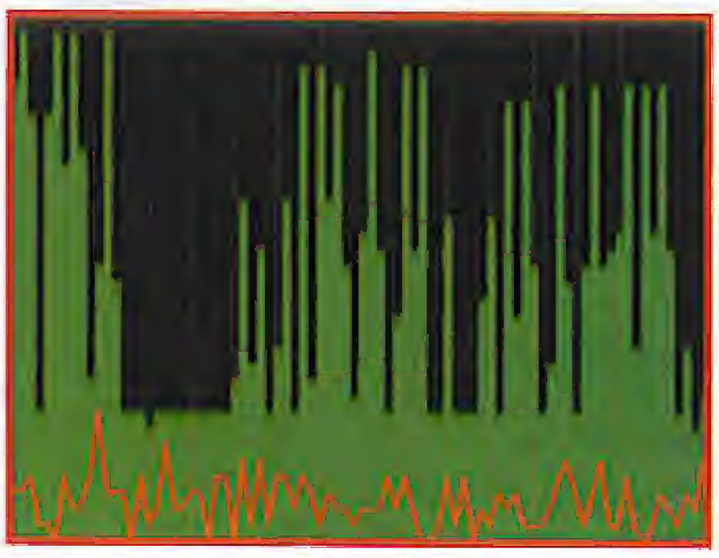


Figure 3c. Bluetooth USB dongle faithfully scanning for other Bluetooth devices.

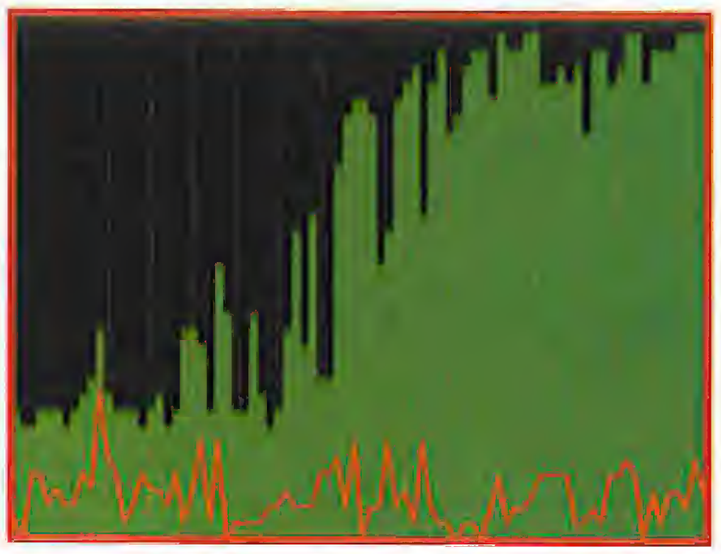


Figure 3d. Microwave oven calling CQ on 2.4 GHz.

vider with a ratio of 0.6 is sufficient to drive 3-V logic.
The SPI signal itself requires RESET, MOSI (data out), MISO (data in), SCK (data clock) and SS (slave select). The latter indicates the start and end of the data transaction. The SPI protocol is a host-driven synchronous signalling interface with the data being sent in MSB (most significant bit) order. The first byte written on the MOSI line contains two control bits and six address bits. A write transaction is followed by another eight bits of data. If a read transaction is being asserted then the slave sends back a byte from the selected address after the initial control byte is written.

Scanning and RSSI

In order to get a picture of the activity in the 2.4 GHz spectrum, the signal generator inside the '6935 must be repetitively swept up in frequency and the signal level at each frequency measured. The frequency generator in the CY-WUSB6935 can be programmed to operate at one of 128 frequencies starting at 2.4 GHz, using intervals of 1 MHz. The ISM band only extends to 2.483 GHz so there is no point scanning beyond this frequency (indeed the device may not actually operate above the 83rd step).
The RSSI circuit in the chip is designed to take a 50 µs snapshot of the incoming signal and make an estimate of the power received at that time. The process of scanning is simple – set the frequency, trigger the RSSI circuit, read the RSSI value after 50 µs.
The RSSI register puts out a value between 0 and 31. According to the datasheet, the range between 0-10 means the received signal level is below –95dBm. The range from 28-31 means the received signal level is above –40dBm. This means each count is approximately –3dBm (i.e.,)

$$(-40) - (-95) / (28-10) = -3.056 \text{ dBm}$$

per count.

The purpose of the register is to give an indication of whether or not something else is transmitting in the band rather than an accurate estimate of the absolute signal power. If there is no signal above a certain threshold, then it should be safe to transmit without fear of being drowned out by other signals at the receiver.
Without some sort of calibration it's not possible to determine the precise power level each register count corresponds to, and may vary from device to device. The datasheet mentions that when scanning for an empty channel, up to 10 reads should be made in order to determine whether or not the channel is indeed clear.

Software

The QTScan software for this program was written to run in Linux and uses QT4 for the GUI. Inside are the parallel port and SPI driver routines. Users of Linux can compile and run the code so long as they have the QT4 runtime and development libraries and headers (for the GUI) and the kernel development libraries and headers (for the parallel port) installed. The binary supplied runs on Ubuntu 6.10 'Edgy Eft' but may work on other recent Linux systems as well. To build QTScan, simply run the executable `make`.

The parallel port should be configured in the BIOS as 'SPP' but depending on your computer hardware it may also work in EPP and ECP mode.
Because SPI is a serial protocol, every byte is serialised and deserialised in software. This serialisation combined with the parallel port running at very slow ISA bus speeds (for historical and backwards compatibility purposes) the scanning software actually runs at a fraction of the speed the chip is capable of scanning at. The scanning speed could be much improved by using a microcontroller with a dedicated SPI port or a general-purpose digital I/O port that is capable of running at much higher speeds. Now there's a challenge — anyone with a successful application running on his/her ARM, PIC24F, R8C or AVR platform should report to Elektor.

Due to the slow nature of the ISA bus parallel port, we measured about 600,000 `ioctl()` functional calls per second that could be executed when reading and writing the parallel port registers. The `inb` and `outb` instructions called by `ioctl()` are stalled by the parallel port hardware for what is an eternity for a modern CPU. This puts a very high system load on the computer, effectively slowing it down while it twiddles its thumbs waiting for the parallel port to complete the `inb` and `outb` transactions.

The software simply sweeps all 83 channels in a repetitive fashion. As you can see from the examples in Figures 3a-2d, QTScan shows the results of the current scan as a red line. In the background, a green histogram captures the peak level detected in each frequency bin. With this device the peak histogram can take tens of seconds to develop a useful picture of ac-

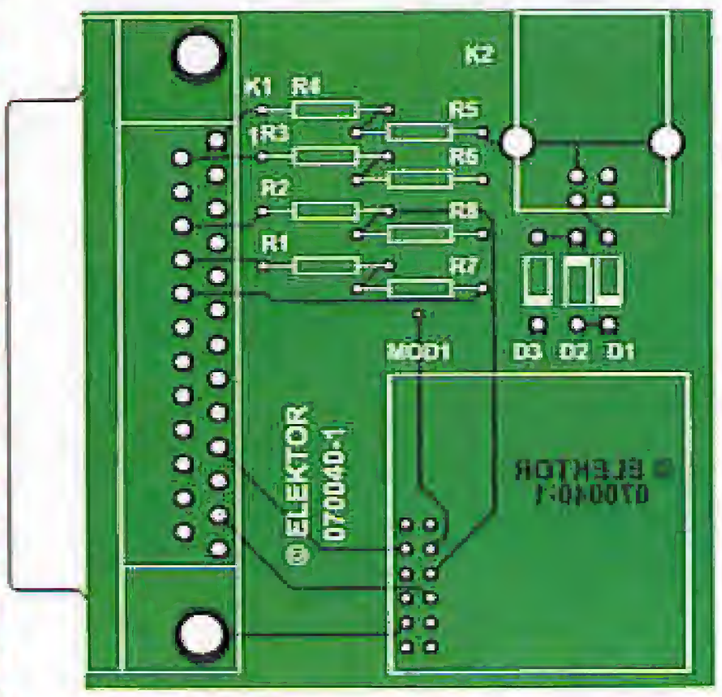
tivity in the 2.4 GHz band, so be patient. Most sweeps however will only produce about one peak per scan.
The vertical yellow lines mark the centre frequency of the 802.11 WiFi channels. The x-axis starts at 2.4 GHz and ends at 2.483 GHz. Each x-axis tick is 1 MHz. The y-axis spans the 32 count levels available in the RSSI register. Assuming the dBm per count levels discussed above, the y-axis starts at –125.6 dBm and ends at –30.8 dBm.
MS Windows software is being developed at the time of writing this article.

All software for this project is available free of charge from the project page on the Elektor website. Simply follow Magazine → June 2007 → 2.4 GHz WiFi Spectrum Analyser, or search for archive file **070040-11.zip**.

Results

The author's household contains various sources of 2.4 GHz radiation, including the computer, microwave oven, Bluetooth devices and an IEEE 802.11b (WiFi) access point. If this sounds familiar to you, read on.

IEEE 802.11b



COMPONENTS LIST

Resistors
R1-R4 = 10kΩ
R5-R8 = 15kΩ

Semiconductors
D1,D2,D3 = 1N4001

Miscellaneous
MOD1 = Cypress module type CYWM6935
K1 = 25-way sub-D plug (male), angled pins, PCB mount
K2 = USB-B connector
PCB, ref. 070040-1 from www.thePCBshop.com

Figure 4. Component mounting plan of the PCB designed for the spectrum analyser.

proc/cpuinfo information said the CPU is running at 2.310 GHz but the peak is shown to be at 2.410GHz in QTScan. It could also be a harmonic from one of the many clocks operating in a modern PC. The signal is present in all the scans.

Bluetooth
Bluetooth devices utilise the entire 2.4 GHz ISM spectrum. **Figure 3c** is a scan of a USB Bluetooth dongle scanning for other Bluetooth devices. It is apparent that it is hopping among many of its own channels in the search for a Bluetooth client device it's eager to talk to. This scan lasted for 10 seconds.

Microwave Oven
It's no accident that the unlicensed 2.4 GHz spectrum falls within the same band allocated to microwave ovens. Such ovens can put out over a kilowatt of (pulsed) broad spectrum microwave power and it's inevitable that some of it will leak out. **Figure 3d** shows the signal levels leaked by the author's microwave oven operating in the kitchen about 5 metres away through two walls. You can see how it swamps the spectrum. WiFi can overcome such interference to a point due to the spread-spectrum process it uses along with packet retransmission techniques. This scan lasted about 50 seconds.

Antenna modifications

The antennas on the PCB are only designed for short-range operation – according to Cypress, up to 50 m or so for the original purposes of data transmission and reception. The on-board antenna could be disconnected (with a knife or scalpel) and an SMA or MCX connector attached to allow for the connection of a larger antenna, either directly or via a length of low-loss coax cable. This would extend the detection range of the device as well as accommodate directionality with the use of an antenna such as a Conifer [4], Pringles cantenna or the Elektor 'precision' Cantenna [5].

Construction

Thanks to the use of a ready-made module there are no gigahertz construction nightmares like tuning PCB striplines, buying PTFE Duroid® board, adjusting oscillators, knowing if the receiver works at all or indeed what GHz stands for.

Design challenge — anyone with a successful application of the CYWUSB6935 running on his/her ARM, PIC24F, R8C or AVR platform should report to Elektor.

Figure 3a shows a WLAN access point operating on channel 9. This scan took two minutes to accumulate all the peaks. The signal displayed comes from the regular beacon signal any access point will continuously transmit. It shows the main lobe centred nicely on the channel 9 indicator line. The lumps either side of the main lobe are the sidelobes typical of a QPSK (quadrature phase shift keying) spectrum. You can also see how the adjacent channels overlap. The best way to ensure that multiple local 802.11b networks aren't interfering is to make sure none of the main lobes overlap.

PC CPU Clock
In the scan in **Figure 3b**, the peak at the left is what's strongly suspected to be emitted from a computer. The /

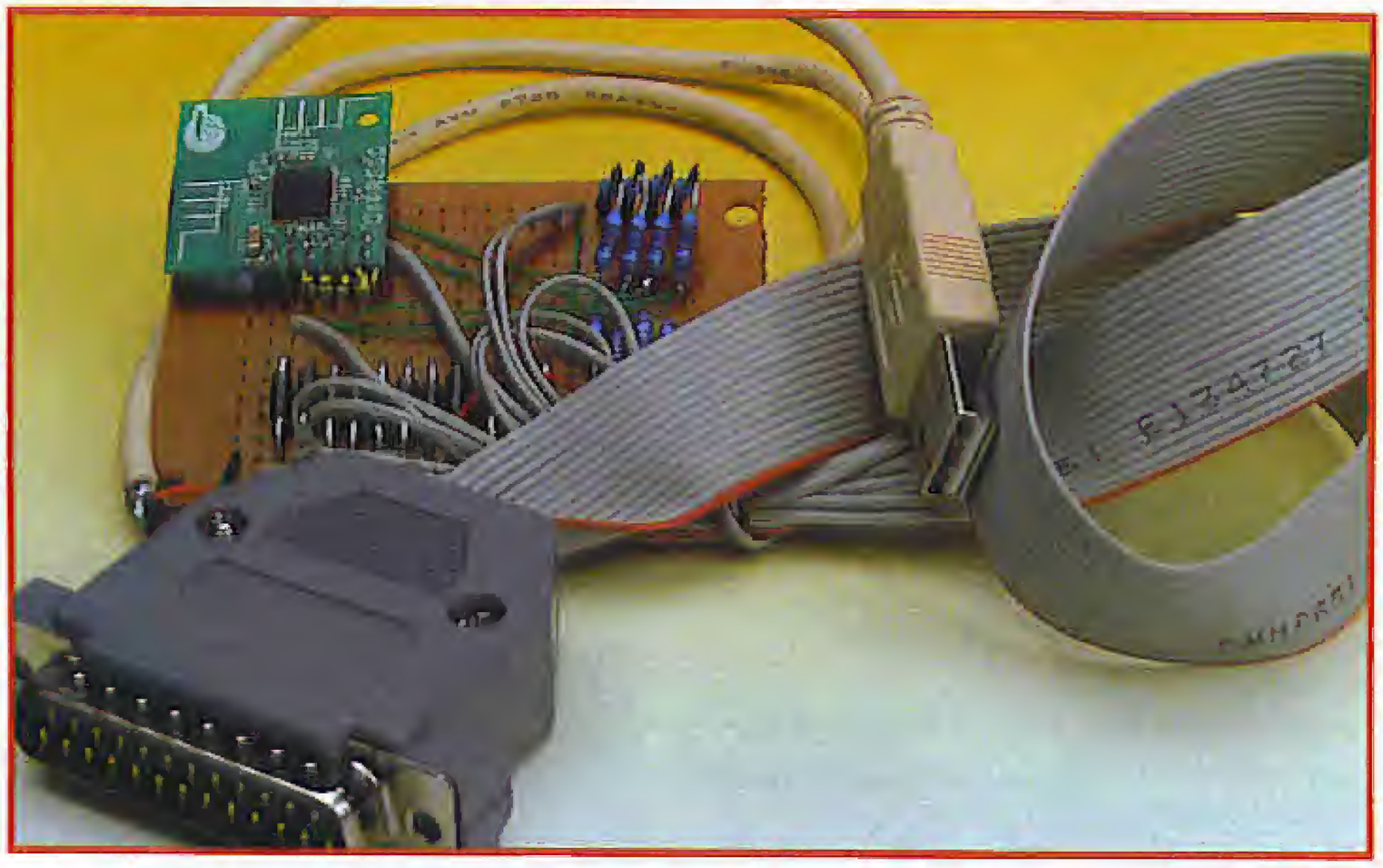


Figure 5. Prototype of the spectrum analyser Jason kindly sent us by mail (from Australia).

The Cypress module and a ridiculously low number of other components are simply mounted on an Elektor-designed PCB of which the artwork is shown in **Figure 4**. The board is available from our business partner The PCBShop (www.thepcbshop.com). Mounting the parts should not present problems.

Finally, Elektor is sometimes criticised for not showing the 'less organized side of things'. Here we apologise and make amends by printing a photograph of the author's prototype of the WiFi spectrum analyser, see **Figure 5**. As you can see it's perfectly possible to construct the circuit on a piece of perfboard. We're now anxiously waiting for emails from SticklersforPerfection & Co. in response to printing an example of 'not so slick' (but fully functional) electronics hardware!

(070040-I)

References and web links

[1] Radio Control using WLAN ICs, Elektor Electronics December 2006.

[2] www.cypress.com/portal/server.pl?space=CommunityPage&control=SetCommunity&CommunityID=209&PageID=259&fid=65&rpn=CYWUSB6935

[3] http://download.cypress.com/published-content/publish/design_resources/datasheets/contents/cywm6935_8.pdf

[4] www.mrx.com.au/wireless/ConfierModifications.htm

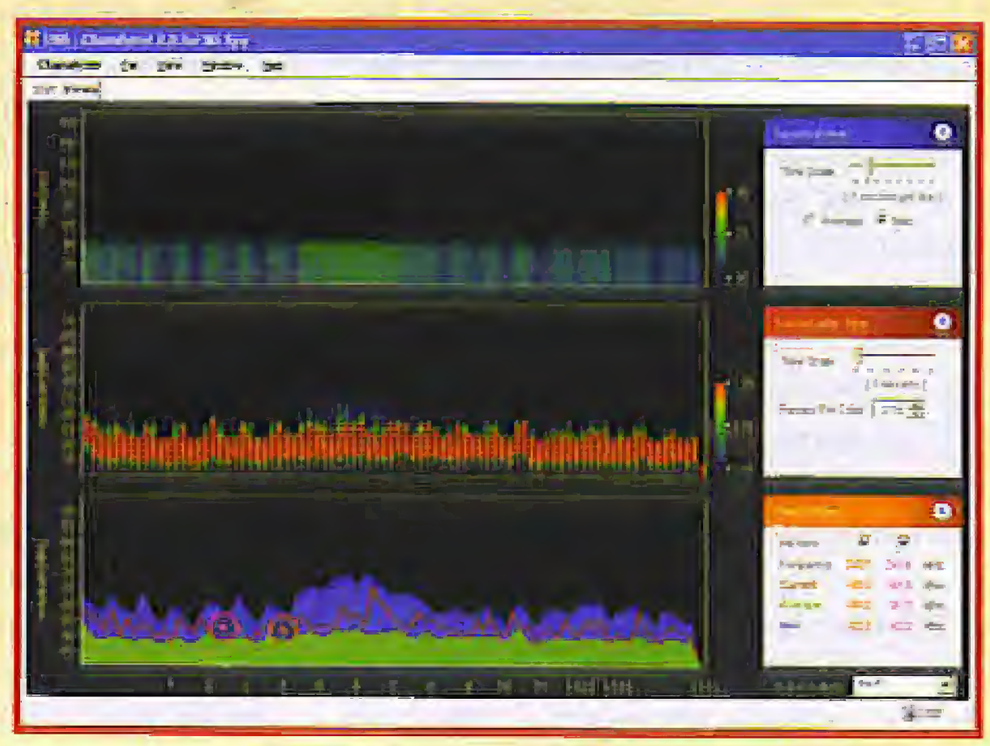
[5] WLAN Antenna Design, Elektor Electronics December 2006.

A commercial unit

The Wi•Spy Spectrum Analyser is proudly announced as "the smallest spectrum analyser in the world, an invaluable tool for making WLAN price quotes, troubleshooting WiFi problems and optimising WiFi implementations".

The hardware actually consists of no more than a carefully sealed USB stick with a length of 4.5 cm. The software supplied on CD is called Chanalyser 2.0 (beta) and hints at metageek.net for its source. Compatibility with Win2000, XP, Linux and MacOS is claimed on the box.

Wi•Spy has some interesting features like data trace, average trace, peak trace, frequency/channel view and record/playback. Remarkably, Wi•Spy is claimed as being able to track down interference from DECT phones, which (we would hope) work between 1.880 and 1.900 GHz i.e., well outside the 2.4 – 2.483 GHz ISM frequency range. But then the receiver inside may be a very wideband type.



The unit costs €119 (approx. £82); we got ours from www.wlan-shop.nl.

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Whistles from on high

Acoustic vertical speed indicator

Thierry Charlès

Let's not beat about the bush: the sole function of the acoustic vertical speed indicator (VSI) described here is to provide an RC model glider pilot with information about the rate of climb (or descent) of the craft.

Designed to detect very small variations in atmospheric pressure so as to enable the pilot of the model fitted with it to keep within an ascent, especially when these are infrequent, our acoustic vertical speed indicator is an example of some of the most complex electronics we're likely to come across, employing both analogue and digital technologies. The project combines RF and LF and for this reason, it calls for extremely careful construction, since the dynamic range of the signals that rub shoulders on the PCB reaches 120 dB.

General

All 'proper' aircraft are fitted with an instrument, the 'VSI' that indicates on a dial the 'rate' of climb or descent (in ft/mn = feet per minute or m/s = metres per second) — in other words, how fast it is climbing or descending. A model glider pilot stands behind a remote control, eyes glued to the sky, and when the air is still, it's sometimes hard to judge the vertical acceleration and catch that 'thermal' that's going to allow the model to soar aloft. Our vertical speed indicator for models is fitted with a pressure sensor. When the glider moves in the vertical plane, the measured atmospheric pressure will vary. The associated electronics converts this pressure change into a vertical acceleration figure that's then used to modulate an audio signal, transmitted via a radio link to the receiver, and thence to the pilot's ears. Climbing is indicated by a high-pitched signal, descending, by a low-pitched one. In each direction of variation (climb/descend), three vertical speed ranges produce three different frequencies. Below the lowest speed threshold, the audio frequency is modulated by the speed, changing from a continuous tone to an intermittent beep.

Target performance

The model flying zone lies at an altitude between 0 m (sea level) and 3,000 m. In order to 'catch a thermal' when the air is still (no wind), the VSI needs to be able to measure a low vertical speed: the target sensitivity is 10 cm/s (< 20 ft/mn).
It is also necessary to be able to pilot the model in real time, so it mustn't wait a whole second before informing the pilot — the reaction time of the circuit (pressure measurement + processing + audio generation + transmission) must be less than half a second.

Block diagram

As the block diagram in **Figure 1** shows, the unit consists of two modules: a transmitter installed in the glider (the top series of blocks) and a receiver on the ground (the bottom series of blocks).
The on-board part consists of an absolute pressure detector, a quad op. amp (the analogue processing chain), an 8-

pin microcontroller (taking care of the digital processing), and a miniature UHF transmitter. A compact power supply makes it possible to draw the power needed (> 200 mW) from a 7 V lithium polymer (LiPo) accumulator, though in fact any self-contained 6/12 V battery or rechargeable would do.

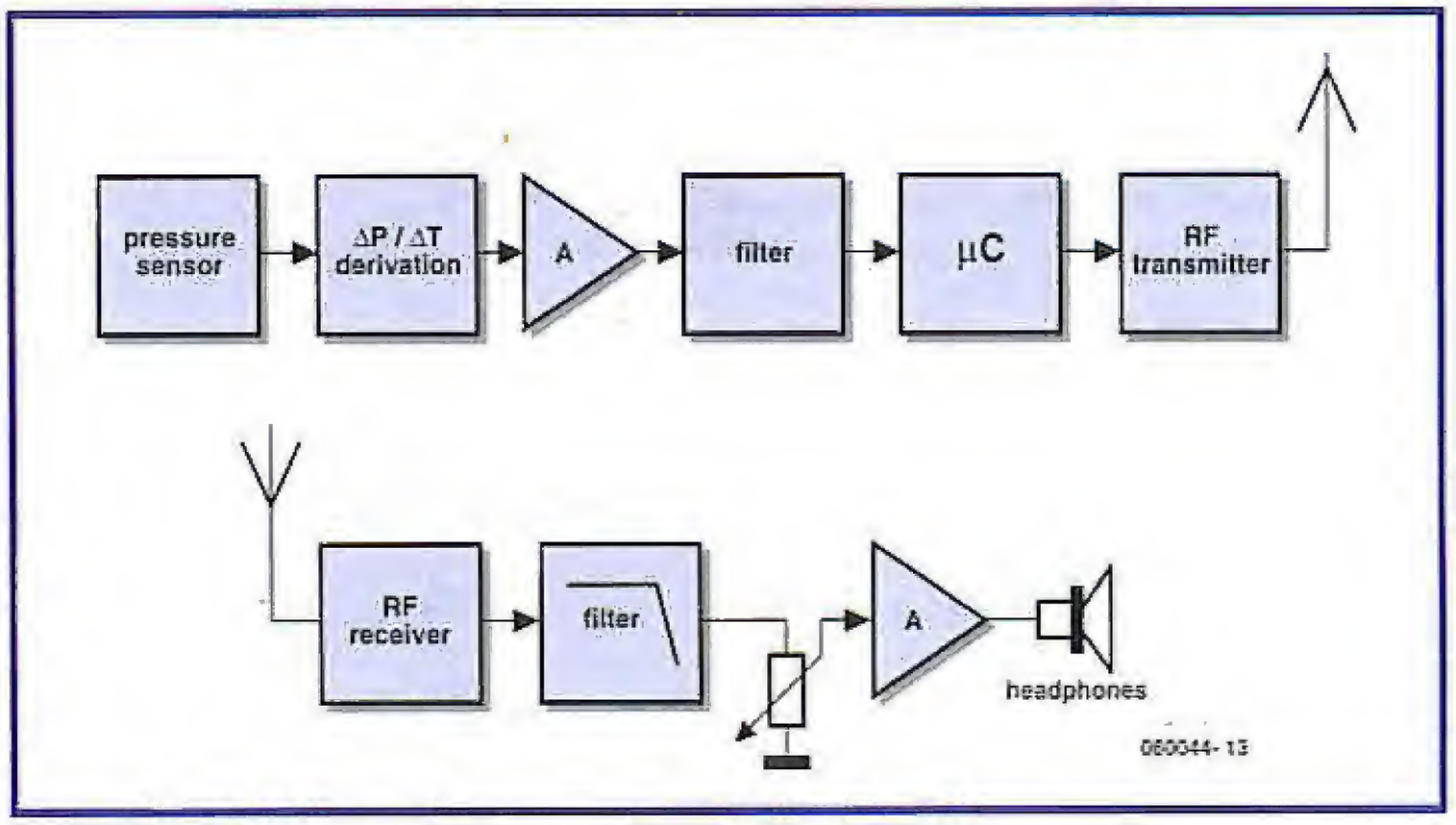


Figure 1. Block diagram of the two sub-assemblies that make up the acoustic VSI: transmitter (top) and receiver (below).

Circuits

Having got an idea of the sub-assemblies that make up this project, now it's time to take a look at the circuit diagrams. To keep things simple, we've subdivided the project into two diagrams, one for the transmitter (**Figure 2**) and one for the receiver (**Figure 3**). Let's start with the most complex one, the transmitter.

Analogue

We opted for an MPX 5100AP sensor (from Motorola, since become Freescale) as it enables us to achieve the desired sensitivity, without being a miniaturized component; what's more, it is compatible with being used in a model, while being readily available at an affordable price (the datasheet can be downloaded from the site provided in reference [7]).

The MPX 5100AP is simple to use: it provides a DC output voltage with a slope of 45 mV/kPa, i.e. 512 µV per metre (at ground level @ 15 °C). So in order to react to 10 cm, the VSI electronics needs to have a sensitivity better than 50 µV.

The voltage provided by the sensor may vary from 0.5 V (0 mb) to 4.75 V (1,100 mb); now the dynamic range of our VSI is limited to between 0 m and 3,000 m; hence the useful output voltage is going to be from 4.75 to 2.95 V. Establishing a virtual earth V_{EE} at 2.5 V enables us to obtain a signed speed output directly from the analogue chain. In the absence of speed, the output is at 2.5 V (virtual earth zero); if the model climbs, the pressure reduces, the sensor output voltage falls, and the analogue chain output signal is negative w.r.t the virtual earth V_{EE}. During descent, the reverse happens.

Let's take a closer look at all that. R10, C7, IC4A are wired as a differentiator. R7 is a compensating resistor to stabilize the gain of the circuit, regardless of phase. Analysis of the circuit shows that it is also a filter with a lower cut-off frequency of 0.23 Hz; this filter eliminates rapid movements that tend to repeat (vibrations). The gain G of the differentiating circuit is set at

$$G = -6.8\ dP / dT$$

IC4B amplifies the signal with a gain $G = 56\times$.

The first-order low-pass filter R6/C8 cutting off at 156 Hz eliminates most of this noise. The function of the last opamp, IC4C, is to match the impedance between the filter and the microcontroller ADC input.

For a vertical speed of 10 cm/s, the wanted signal out of the pressure sensor (dP/dT) is 51.2 µV, which is detected and amplified by the analogue

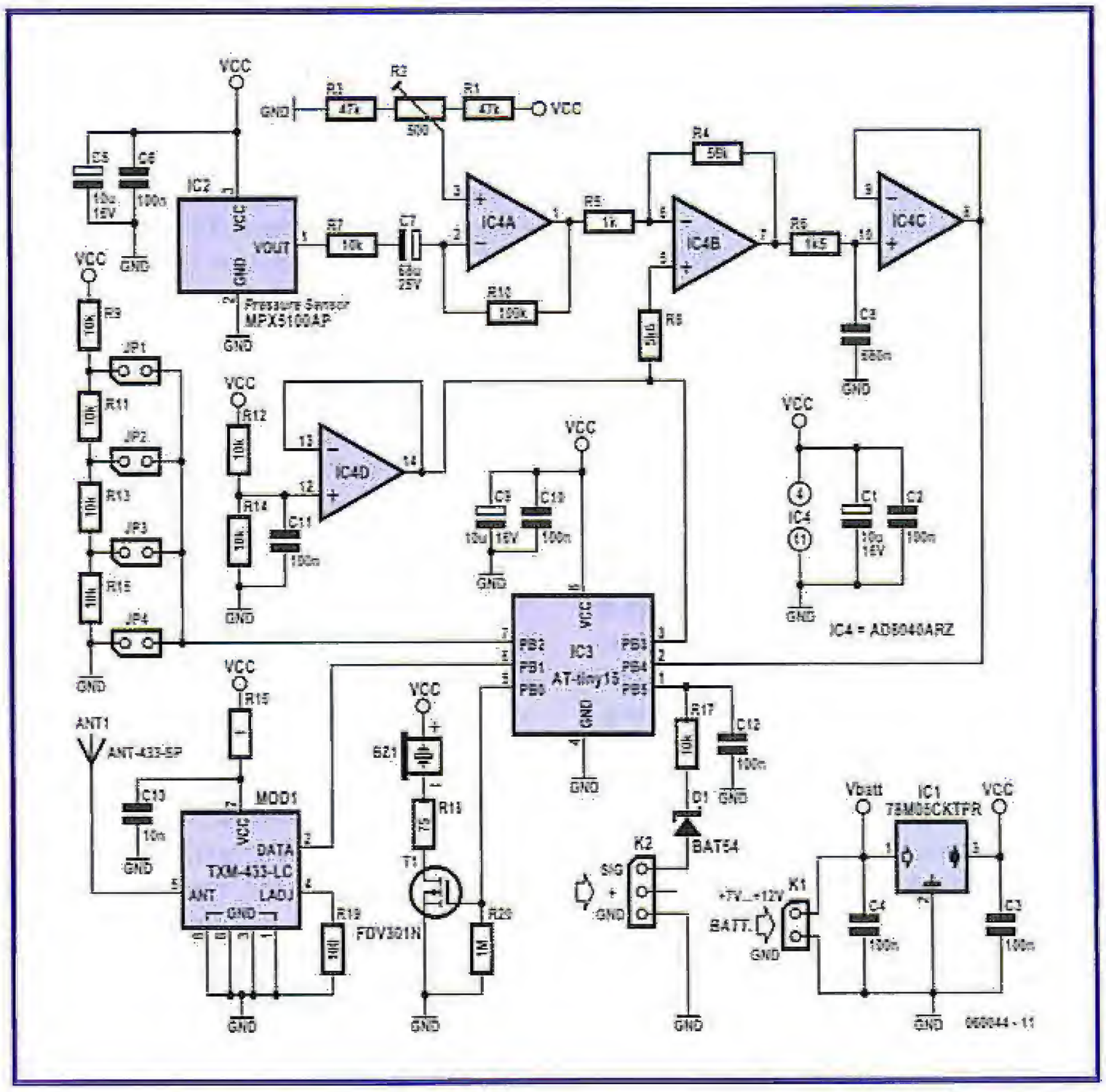


Figure 2. Transmitter circuit diagram. The integrated aerial and the sensor are the bulkiest components.

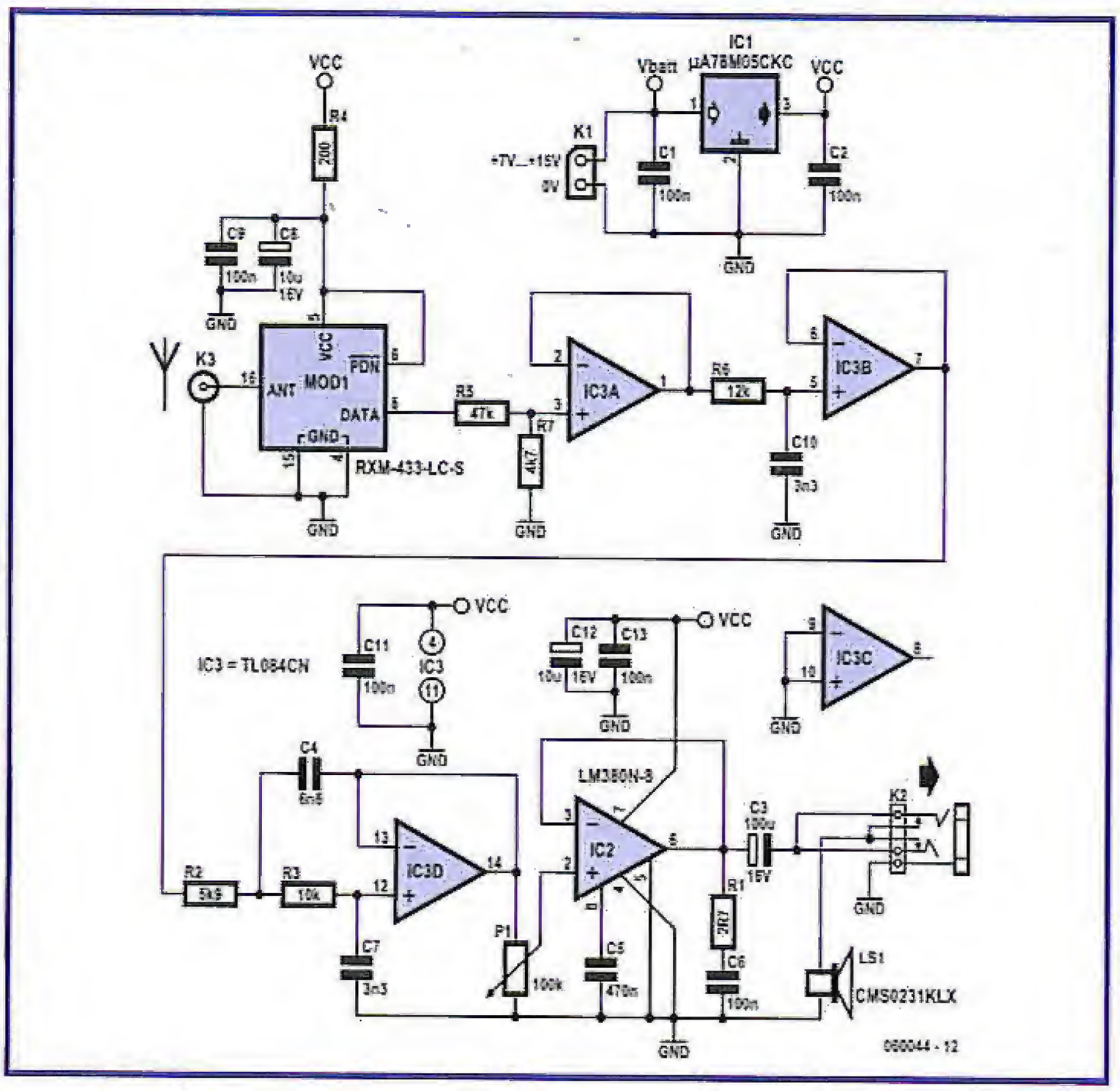


Figure 3. The receiver circuit amounts to very little really, as the integrated module does the lion's share of the work.

processing chain; at the input to the microcontroller this wanted signal (19.3 mV) is drowned in noise and offset by the offset voltage.
Signal processing is performed digitally by the microcontroller.

Digital

The digital processing chain extracts the wanted signal from this noisy information, then calculates the relevant speed and delivers the audio signal.
The microcontroller we've chosen is the ATMEL ATtiny 15L, which is powerful enough despite its 8 pins, with four 10-bit ADC inputs, two programmable counters, and an EEPROM. What's more, it can operate without any additional components (crystal, voltage reference, Reset, etc.). Choosing V_{CC} as the reference voltage, the 10-bit ADC has a resolution of 2^{10} i.e. 5 V ÷ 1,024 = 4.88 mV, defining the circuit's sensitivity threshold at 12.8 μV, i.e., 2.5 cm/s (12.8 μV × 6.8 × 52).
An interrupt triggers the program every 5 ms. Each interrupt prepares an A-D conversion in the following order: the virtual earth, the speed, the absolute pressure, the battery voltage. Thus each of these parameters is encoded at 50 Hz.
To extract the wanted signal, the software performs three filtering operations. The first supplies the mean value of five consecutive measurements, thus providing a filtered speed across five samples at 10 Hz. The second filter performs a rolling average at 10 Hz of the last *n* (where *n* is configurable) values of the filtered speed. The speed value obtained at the output of this second filter stage is used to produce the audible signal.
The third stage of processing is enabled when the speed signal produced at the output of the second filter remains within the 'configurable' level flight limits (± 20 cm/s or ± 30cm/s, i.e. when the vertical speed is less than 3 or 4 cm/s) for 7.2 seconds at a stretch. This filtering derives the mean value of the residual noise, on the assumption that it in fact represents the offset at the output of the analogue chain; the relevant value is used to 'digitally offset' the virtual earth value. Thus the bias at the analogue chain output is compensated for in real time.
Together, all this processing increases the sensitivity dynamically to bring the noise amplitude on the wanted speed to ± 2 LSB (± 5 cm/s).
In the presence of this processing, having defined (in consultation with end users) the minimum detectable speed threshold at 20 cm/s (by clipping), on the bench the circuit does not produce any spurious audible signal, unless there's a forecast of storms....
Below the 'level flight' speed threshold, the software considers that the model is flying level.
To produce the audible signal, four speed values have been defined: 50 cm/s, 75 cm/s, 1 m/s, and 2 m/s. Below 1 m/s, the audio frequency is generated at 625 Hz descending and 1,000 Hz climbing, and is modulated by the speed, going from a keyed tone at the lowest speed to a continuous tone at 1 m/s. Between 1 and 2 m/s, the sound is continuous at 1,250 Hz climbing or 430 Hz descending. Beyond 2 m/s, a continuous tone of 1,650 Hz climbing and 310 Hz descending is produced.
The on/off modulation (keying) below 1 m/s increases below 75 and then 50 cm/s to enable variations at slower speeds to be detected.

Table

Speed	Climbing	Descending
<30 cm/s	Nothing	Nothing
<1 m/s	1,000 Hz keyed	625 Hz keyed
>1 m/s	1,250 Hz steady	430 Hz steady
>2 m/s	1,650 Hz steady	310 Hz steady

The audio generation needs to be 'decoupled' from the continuous, rapid speed variations.
Without this processing, the audio signal is constantly varying and hence difficult to interpret. To obtain 'meaningful' audio information, the audio generation processing takes the maximum speed value produced over three cycles (the maximum value measured every 300 ms).
To achieve maximum sensitivity in the analogue chain, the circuit needs to have reached thermal stability and the differentiating capacitor to 'have reached charge balance'.
In order to differentiate an almost continuous voltage (frequency < 0.1 Hz), the capacitor charging time constant is long. From a cold start, stable operation is reached after 20 minutes; from a 'hot

start', the operating point is reached 3–5 minutes after power-up.
This difference is partly due to the temperature stabilization, as well as to the fact that when hot starting, the differentiating capacitor is already partially charged.
Operating initialization takes place in three stages:
1. the voltage at the ADC falls rapidly from 2.5 V to 195.2 mV (the differential voltage between pins 3 and 2 of the microcontroller) in less than 3 minutes; this delay will varies, as it depends on the type of start: cold or hot. During this phase the audio output produces an 800 Hz signal on/off modulated; flying is possible, but strongly to be discouraged.
2. The ADC input voltage is below 190 mV, the level flight threshold is set at 30 cm/s and the microcontroller 'compensates' for the offset at its analogue input. This compensation is established in two ways: by adjusting the offset dynamically by means of regular self-calibration while the measured speed remains below ± 30 cm/s (assumed to mean level flight); and by superimposing on this first compensation inverse correction (predefined) for the differentiating capacitor charging. During this phase, flying is possible, albeit with slightly reduced performance: reduced sensitivity and a risk of the appearance of a slight bias on the audio output.
3. Once the offset correction calculated in phase 2 falls below ± 20 cm/s, the first successful self-calibration ends the operational initialization process and automatically selects a sensitivity of ± 20 cm/s.

Developing the software

The code was written in assembler, using the tools provided by ATMEL, Studio 3.5 then Studio 4, available on free download from the ATMEL website (Ref [8]). Once you've got the hang of this tool, writing, debugging and emulating become child's play.

The program VMR-0-4.hex will be loaded into Flash memory, using one of the suitable commercially-available tools; in developing this project, the STK 500 tool was used in conjunction with Studio 4.

After loading, the microcontroller has to be configured in order to function correctly: RESET = internal, BROWNOUT = 4 V, and it is preferable, though not essential, to use the internal clock calibration constant. Numerous examples of code (Assembler and C) are available on the ATMEL website, obviating the need to write everything from scratch (Ref. [9]). The documentation that enables us exploit the microcontroller's resources correctly is comprehensive and contains a wealth of information. You can also download the detailed spec. sheet for the microcontroller from the ATMEL website (Ref. [10]).

Once created and tidied up, the VMR-0-4 software occupies 99 % of the Flash memory and 40 % of the EEPROM.

The software runs at a rate determined Timer 0 which supplies an interrupt every 5 ms (processing time 200 µs). Every five cycles, the main process is run (process time < 400 µs).

The background task manages switching between the main task of processing, putting the microcontroller into standby, and the audio output; it takes less than 50 µs.

In assembler, processing times are extremely short.

For this application, the processing time is not a constraining factor, the main problem is posed by the EEPROM write time — as there is no RAM, use has to be made of the EEPROM resources to store the data. The duration of a write cycle is 8,192 machine cycles, i.e. 5.12 ms at a clock frequency of 1.6 MHz. The processing task performed at 50 Hz performs three writes and 16 reads; there is no constraint on the read duration.

This task requires a processing time of 3 x 5.1 ms = 15 ms, which is still compatible with the 20 ms cycle time. To limit the effects of an uncontrolled process, the interrupt generator that sets the processing rate to 5 ms is interrupted during this task.

RF section

The RF transmitter is the smallest possible, and the frequency the highest permitted, so as to ensure frequency-compatibility with the radio-control receiver and limit the size of the on-board aerial. We chose the TXM-433 from LINX Technologies. The summary, just about adequate, datasheet can be downloaded from the Internet (Ref. [3]). With a standard receiver, as well as with a dedicated receiver specially built for this application, the range is sufficient.
The 50 Ω transmitter aerial has been designed for the most even radiation pattern, whilst taking very little space. So we opted for a planar-type integrated aerial, the 433-SP2 'Splatch' from LINX (them again!). Opting for this type of aerial allows us to produce an extremely compact transmitter. Nothing overhangs the board, not even the pressure sensor.
This leaves the receiver to talk about. This version of the receiver, the circuit shown in **Figure 3**, is extremely simple: an RXM-433-LC-S RF receiver, also from LINX Technologies, a low-pass filter to suppress everything except the wanted audio signal, and an amplifier.

Power supply

The circuit could be powered from the model's own battery — to do so, all you need do is replace IC1 by a protective choke. Although this solution does make it possible to limit the space occupied and the weight, it is not really to be recommended. Models are powered from a battery whose voltage varies from 4.7 to 5.6 V at full charge. This supply voltage variation, along with the interference generated by the servo motors, is not conducive to correct operation of the analogue chain and achieving the required sensitivity.
The processing chain needs a stabilised, regulated 5 V supply, and the virtual earth must be 'centred' with an error of less than 1 mV. In order to avoid potential interference that could disrupt the operation of the VSI or the model, the circuit is designed to be supplied from a dedicated battery.

Construction

The two PCBs, whose component overlays are shown in **Figures 4** and **5**, require careful construction, and the

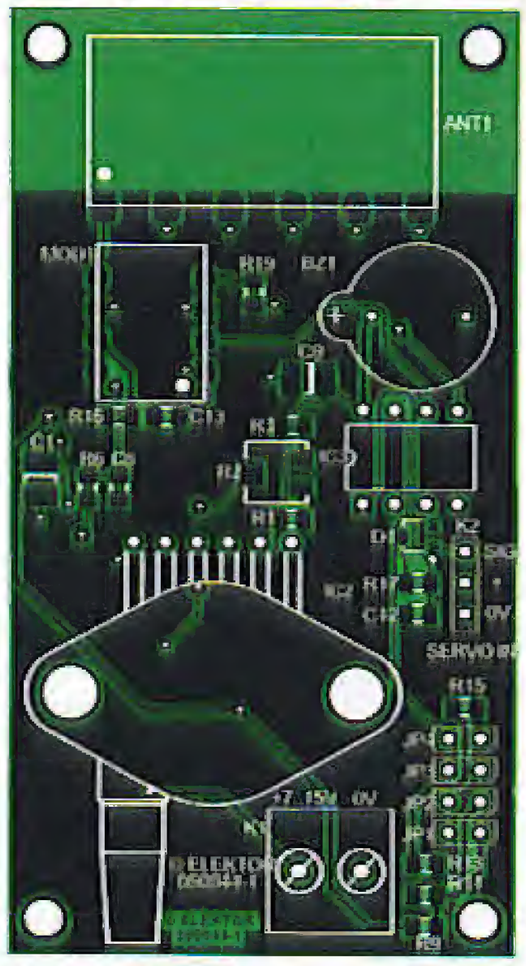
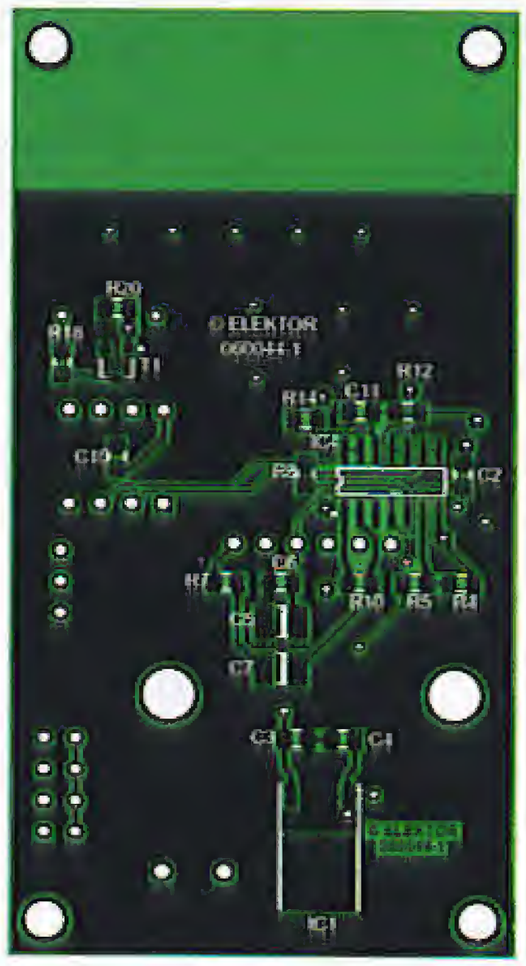
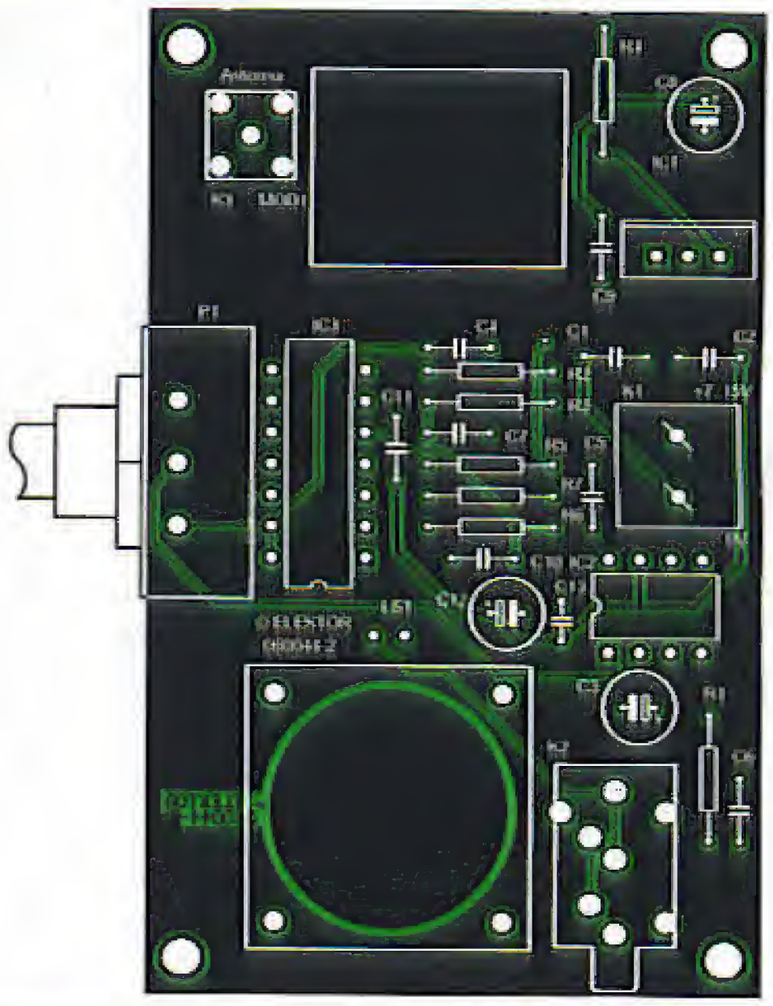


Figure 4. Transmitter component overlay.





pair of cross-tipped tweezers for holding the SMDs in place while you solder them.

• Fit the aerial and solder it to the six connection points provided.

• Before applying power to the circuit, use a multimeter to check the supply rails connections to the relevant device pins.

• Position the sensor, taking care that the fixing holes are correctly aligned. To ensure good mechanical fixing, you can if you wish insert two flat washers between the sensor and the PCB and then fix it using two PTFE screws; then solder it.

• Add a cable-tie if necessary onto one of the fixing screws so as to 'lace' the wiring to the circuit.

Solder the op. amp on the underside of the board, then solder the eight contacts (once again, it's hard to talk of 'pins'!) of the RF transmitter.

Don't plug the microcontroller into its socket yet, but instead connect an oscilloscope between pins 2 and 3 of its socket.

Note: the sounder BZ1 could be fitted in the space provided for it — it will be able to be used to identify the model, once the software is modified for this purpose (function not yet available at time of writing).

Now let's move on to constructing the receiver. Here again, we have a through-hole plated, double-sided PCB. Most of the components here are conventional devices, except for the receiver module itself, which is an SMD. The layout is relatively dense. You should start by fitting the SMD module, then the smaller components. The rest of the components don't need any special comment. The miniature speaker will be positioned on the underside. You might also consider fixing it onto the cover of the case, linking it to the points provided using two short lengths of flexible wire.

Initial testing

After checking the quality of your construction, connect up the battery (take care if you are using an earthed bench supply with the oscilloscope, which could take the virtual earth down to true earth). The output signal is saturated for a few tens of seconds, then it will gradually go down to virtual earth (0 V on the screen, 2.5 V in absolute terms).

Turn off the power, load the software into the microcontroller using a suitable tool (or buy the microcontroller ready programmed from Elektor), and insert it into its socket. Before powering up, set the VSI on a firm support so it can't move. Close doors and windows (to avoid detecting draughts and limit interference from ambient pressure changes).

After power on, the software starts up in 'operational initialization' mode — in this state it emits an intermittent 800 Hz audio signal. This state is maintained for less than three minutes, as long as the microcontroller does not detect a change to below 1 m/s over a period of 3 seconds. Then the sound stops, and the VSI is all ready to fly.

The operational initialization continues transparently for as long as the microcontroller input offset measured by the self-calibration process is not within the level flight range (± 20 cm/s). It is advisable to leave the circuit permanently powered so as to help the zero seeking by the software. Breaks in power and battery disconnections must be spaced apart by two minutes.

To test operation, all you need do is open or close the door of the room — the VSI will detect the pressure variation caused by opening or closing the door.

Plugging a loudspeaker jack into the socket provided cuts off the internal speaker. That way you'll avoid noise pollution that your modelling colleagues would gladly do without.

All that remains is to test the circuit in the demanding aeromodelling environment. Good luck!

Future

In the 'VMR 0-4' version of the software, the audio signal is generated 'on board', and it is not possible to fly two VSIs at the same time near one another, as the RF signals interfere with each other upon reception. However, the equipment architecture has been designed to allow five units to be flown simultaneously; this functionality could be available in a later version of the software.

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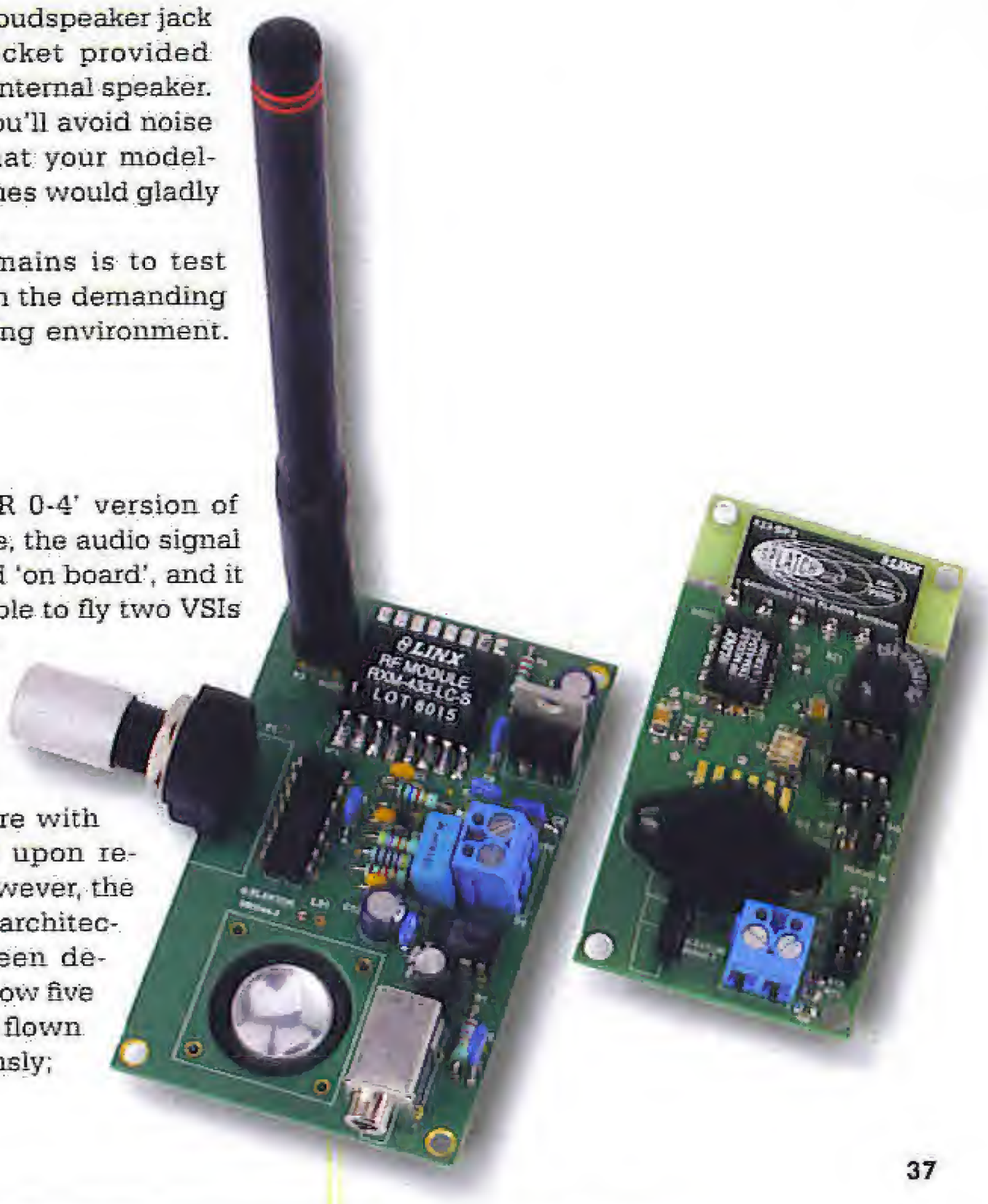

Web links

[1] www.freescale.com/files/sensors/doc/app_note/AN1646.pdf

[2] www.freescale.com/files/sensors/doc/

[3] www.linxtechnologies.com/Documents/TXM-xxx-LC_Data_Guide.pdf

[4] http://membres.lycos.fr/cepls/plan.html

[5] http://courelectr.free.fr/AOP/COURS.HTM

[6] www.freescale.com/files/sensors/doc/app_note/AN1100.pdf

[7] www.freescale.com/files/sensors/doc/data_sheet/MPX5100.pdf

[8] www.atmel.com/dyn/products/tools_card.asp?tool_id=2724

[9] www.atmel.com/dyn/products/app_notes.asp?family_id=607

[10] www.atmel.com/dyn/resources/prod_documents/doc1187.pdf

Tube Sound

Wim de Jager

It is 100 years ago this year that the triode was invented by Lee de Forest. It is remarkable that triode output stages still occupy an important place in high-end audio amplifiers. Triode amplifiers are often very expensive. The design presented here is based on a combination of optimal quality and reasonable construction cost.

Specifications

Test measurements carried out with a load of 8 Ω

Output power (1 kHz, 2%):	9.5 W into 4 Ω and 8 Ω	
Input sensitivity (9 W, 1 kHz):	200 mV (without negative feedback)	600 mV (with negative feedback)
Output impedance (1 kHz):	2.3 Ω (without negative feedback)	0.8 Ω (with negative feedback)
Bandwidth (1 W):	20 Hz to 27 kHz (without negative feedback)	< 20 Hz to 64 kHz (with negative feedback)
THD + noise (1 W, 1 kHz):	0.15% (with negative feedback)	0.3% (without negative feedback)
Hum/noise:	–72 dB (without negative feedback)	–82 dB (with negative feedback)

The subject of "Tubes versus Transistors" has already been frequently discussed in literature. Instead of repeating it all, we are offering a reference instead. A comprehensive comparison is presented in the article 'Vacuum Tubes and Transistors Compared' (refer http://milbert.com/TVTFC.bdc). In addition to triodes, pentodes are also used for audio amplifiers. The choice between these two is made on the basis of a number of considerations.

Triode or pentode?

With triodes, the influence of the anode voltage on the anode current (negative feedback) is quite large (see **Figure 1a**). The result of this is a lower output impedance and a smaller amplification factor 'μ' (this is the maximum achievable voltage amplification when there is a DC current source in the anode path).

With pentodes (see **Figure 1b**), the screen grid voltage in particular determines the anode current. As a result, the influence of the anode voltage on the anode current is smaller, which results in a higher output impedance and therefore a higher μ.

The disadvantages of pentode output stages are:

1. Loudspeaker damping is practically zero and negative feedback is required to reduce the output impedance of the amplifier to an acceptable value.
2. The damping of transformer resonances is so small that in the absence of a load (open-circuit output) very strong oscillations can be generated with voltages that can become so high arc-over occurs in the valve sockets or output transformer.

With triodes, the loudspeaker damping and transformer resonance damping are much more favourable because of a lower μ.

The disadvantages of triode output stages are:

1. The consequence of a lower μ means that the driving stage has to be able to supply a signal with relatively large amplitude.
2. Because of the lower output impedance the influence of power supply ripple is larger with triodes than it is with pentodes. This means that the power supply smoothing filter has to meet higher requirements.

Single-ended or push-pull?

The distortions of a triode and a pentode are compared in **Figure 2**. This shows that with triodes d2 is dominant

Class-A triode push-pull amplifier

and d3 with pentodes. Even-numbered harmonics are largely cancelled in push-pull circuits, odd-numbered harmonics are not. The result of this is that a triode push-pull amplifier has a lower open-loop distortion than a pentode push-pull amplifier, mostly due to the third harmonic (d3).

The second advantage of a push-pull amplifier is that with correct DC biasing there is no DC bias in the core of the output transformer. The core can there-

Figure 1. The characteristics of a triode and a pentode.

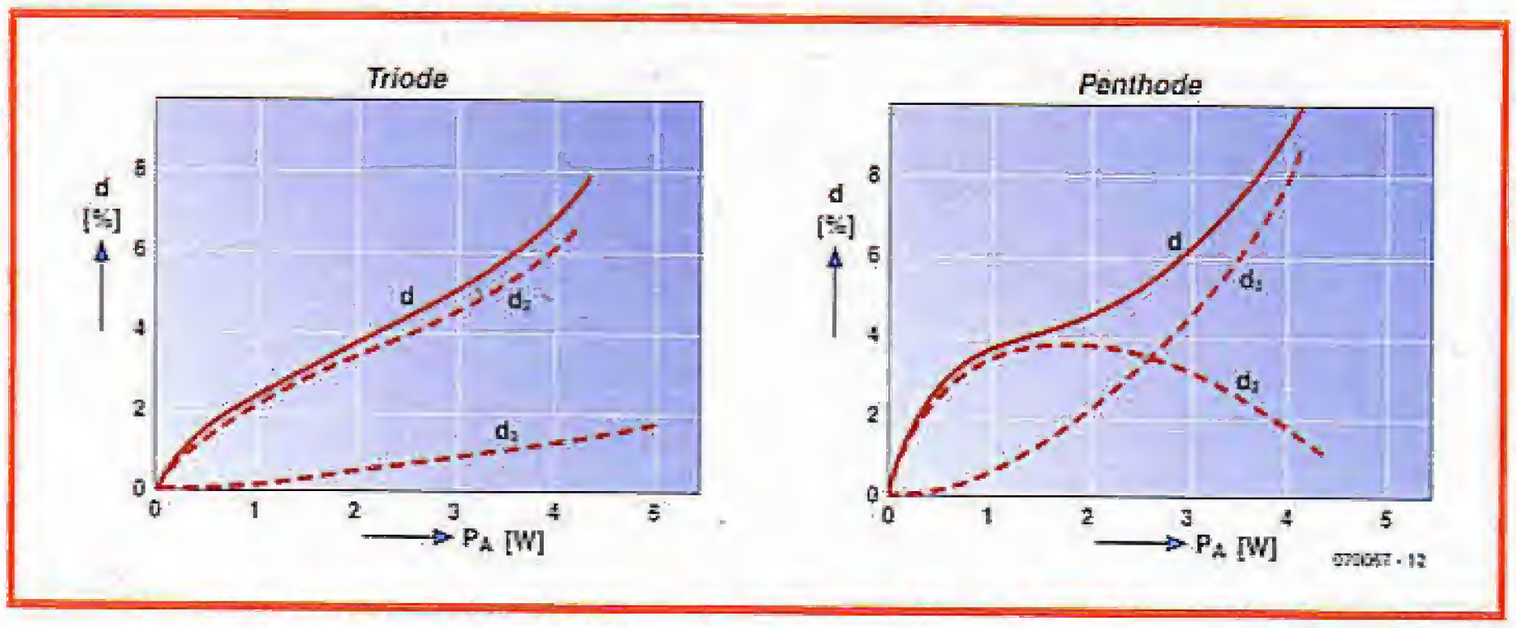

Figure 2. Distortion with a triode and a pentode.

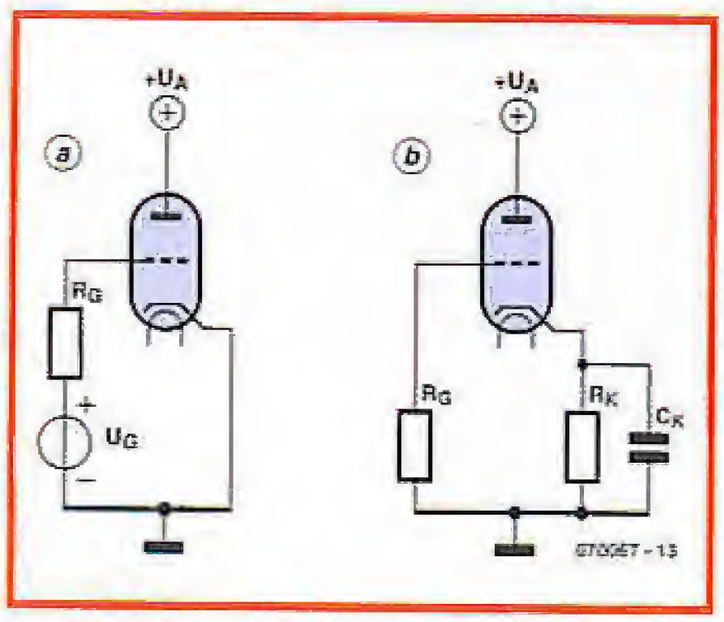

Figure 3. a: Fixed value of grid voltage. b: With the aid of a cathode resistor a simple automatic negative grid voltage adjustment can be made.

fore be smaller, and as a result the transformer is cheaper to make. Also, the effect of the power supply ripple is mostly cancelled in the output stage.
A disadvantage of a push-pull amplifier is the requirement of a phase shifter to drive the output stage with two signals that have equal amplitude and opposite phase.

Output power and efficiency

It is incorrect to think that sound appears twice as loud to the ear when the power rating of the amplifier is two times larger. The sensitivity of our ears is logarithmic and has a range of 0 dB (threshold of audibility) to 120 dB (pain threshold). Doubling the output power of an amplifier gives a power gain of 3 dB.

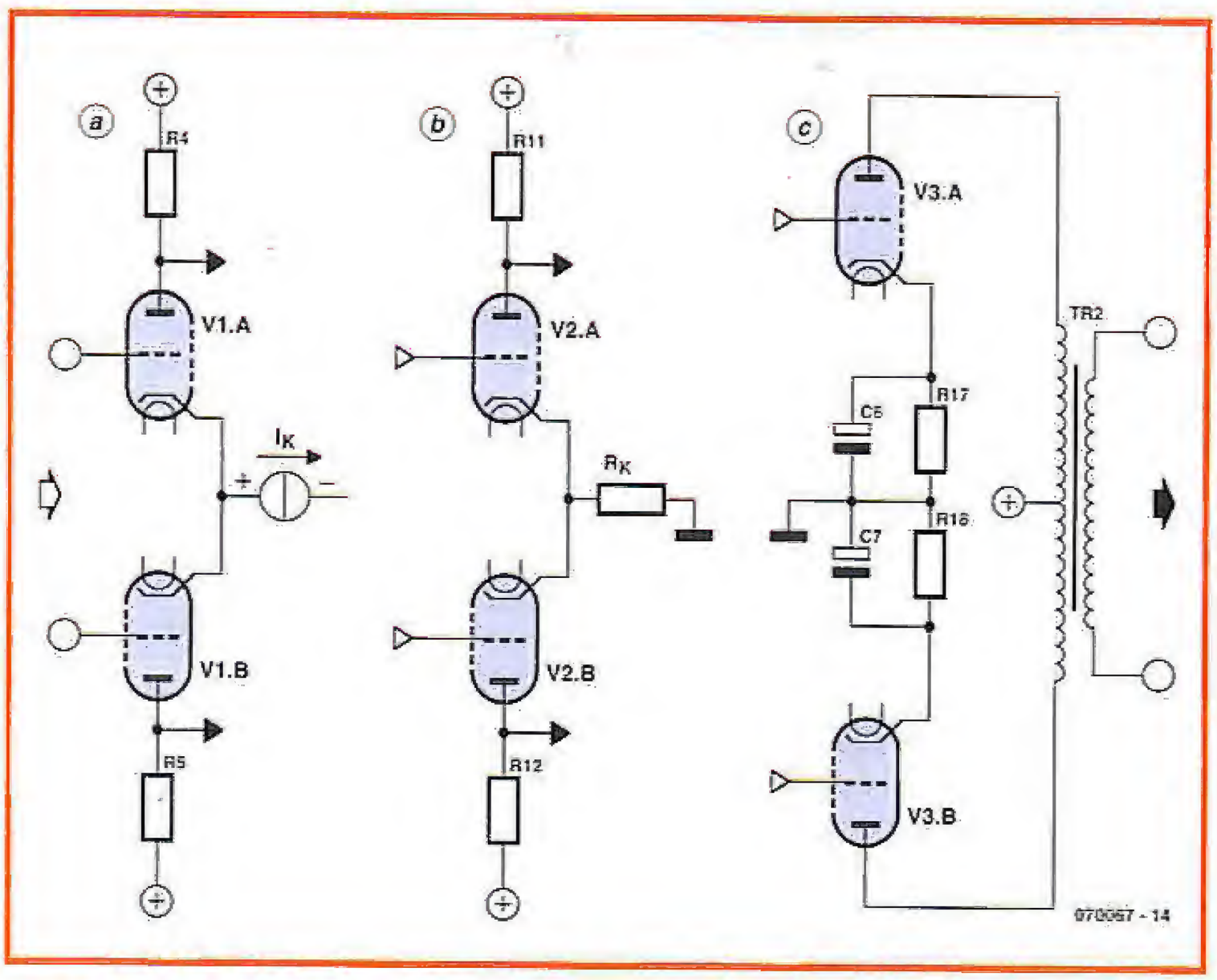

Figure 4. Principle schematic for the triode push-pull amplifier.

The amplifier published in this article delivers an output power of 2×9 watts at a THD (total harmonic distortion) of 2% (open-loop). This is a reasonable amount of power considering the logarithmic characteristics of our ears, and also because of the soft-clipping behaviour (excessive signal peaks do not lead to 'aggressive' distortion). If desired, high-efficiency loudspeakers could also be used.
The valve handbook from Philips [3] states that a pentode push-pull output stage with 2× EL34 has an efficiency of 53%. This does, however, not take into account the dissipation of the screen grid. This should be included for a fair comparison between triode and pentode output stages. Including the screen grid dissipation the efficiency is 42%. The efficiency of the triode push-pull amplifier presented here amount to 35%, so that is still competitive.

Distortion

The audibility of distortion is strongly dependent on the spectrum. Crossover distortion in transistor amplifiers is very annoying because it has a very broad spectrum. In addition, this distortion increases at lower output powers. With valve amplifiers, the concerns are with lower-order harmonics and according to Douglas Self [4] the threshold of audibility in this case is around 1%. There is therefore very little motivation to design valve amplifiers with lower distortion.

DC bias setting

A fixed negative grid voltage (**Figure 3a**) has the disadvantage that the DC bias setting is dependent on device tolerances and ageing of the valve. It is often necessary to make manual corrections for the DC bias setting to obtain the desired result. With an automatic negative grid voltage (**Figure 3b**) the grid-cathode voltage is determined by the voltage drop across cathode resistor R_k, which is caused by the cathode current. In this method of negative feedback, R_k determines the DC bias setting in a significant way and the effects of valve parameters are strongly reduced. If AC negative feedback is not desired then R_k typically needs to be decoupled with an electrolytic capacitor.

Simplified schematic

In **Figure 4**, the simplified schematic for the amplifier, the RC coupling components between the different stages have

been omitted for simplicity's sake.
The low μ of the triodes used makes a 3-stage approach necessary. For the DC bias setting of the output stage, an automatic negative grid adjustment was chosen, separate for each triode. As a result, the DC offset is much smaller compared to a common cathode resistor and this is advantageous with respect to the potential DC bias in the output transformer. Decoupling of the cathode resistors is necessary to prevent the preamplifier from having to deliver an even larger drive voltage.
The output stage of a push-pull amplifier is often driven by a phase shifter. This is not recommended with triode output stages because the wave shapes of the output signals of the phase shifter are not equal at very large signal swings, which would result in more distortion in the output stage than is necessary. The second stage in this amplifier employs a push-pull amplifier with a common cathode resistor. This resistor is not decoupled because the AC cathode currents are in opposite phase and therefore do not cause a voltage drop across R_k. The first stage is a differential amplifier, used as a phase shifter. From all the circuits that are suitable for this purpose, this is the only type where both input terminals remain freely available. By doing so, the design becomes similar to that of an opamp, which means that the usual methods for negative feedback around opamps can be used here as well. The implementation of the current source I_k can be a resistor, the ohmic value of which must be much greater than the 1/S of the valves (where S is the mutual conductance). This requires a negative power supply voltage of $\geq 50\ V_{DC}$.
An important advantage of this design is the complete push-pull structure so that the distortion and sensitivity to hum and interference are minimal.

The complete amplifier

Figure 5 shows the complete schematic

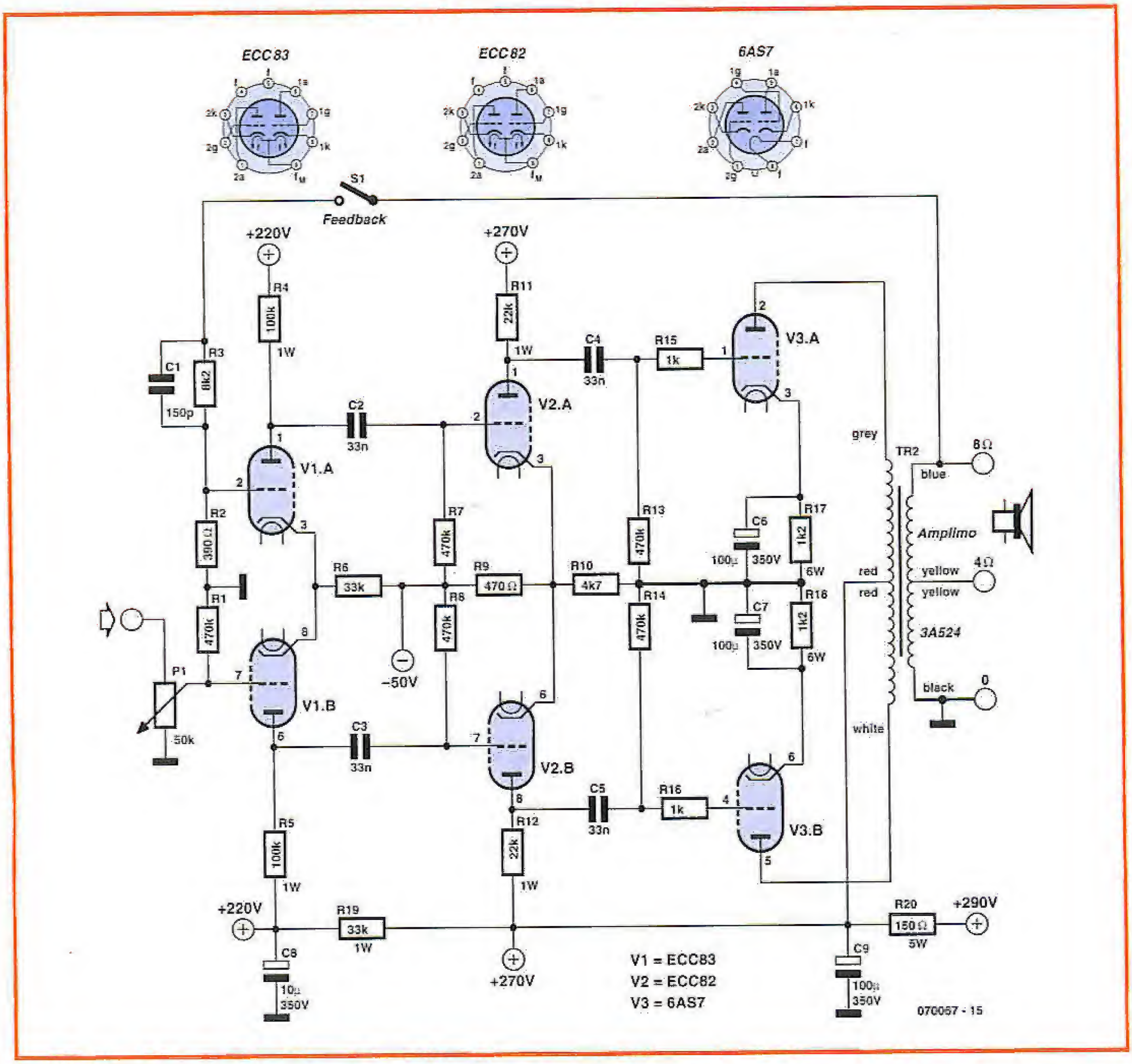

Figure 5. The complete schematic of the amplifier (one channel shown). Note the switchable negative feedback.

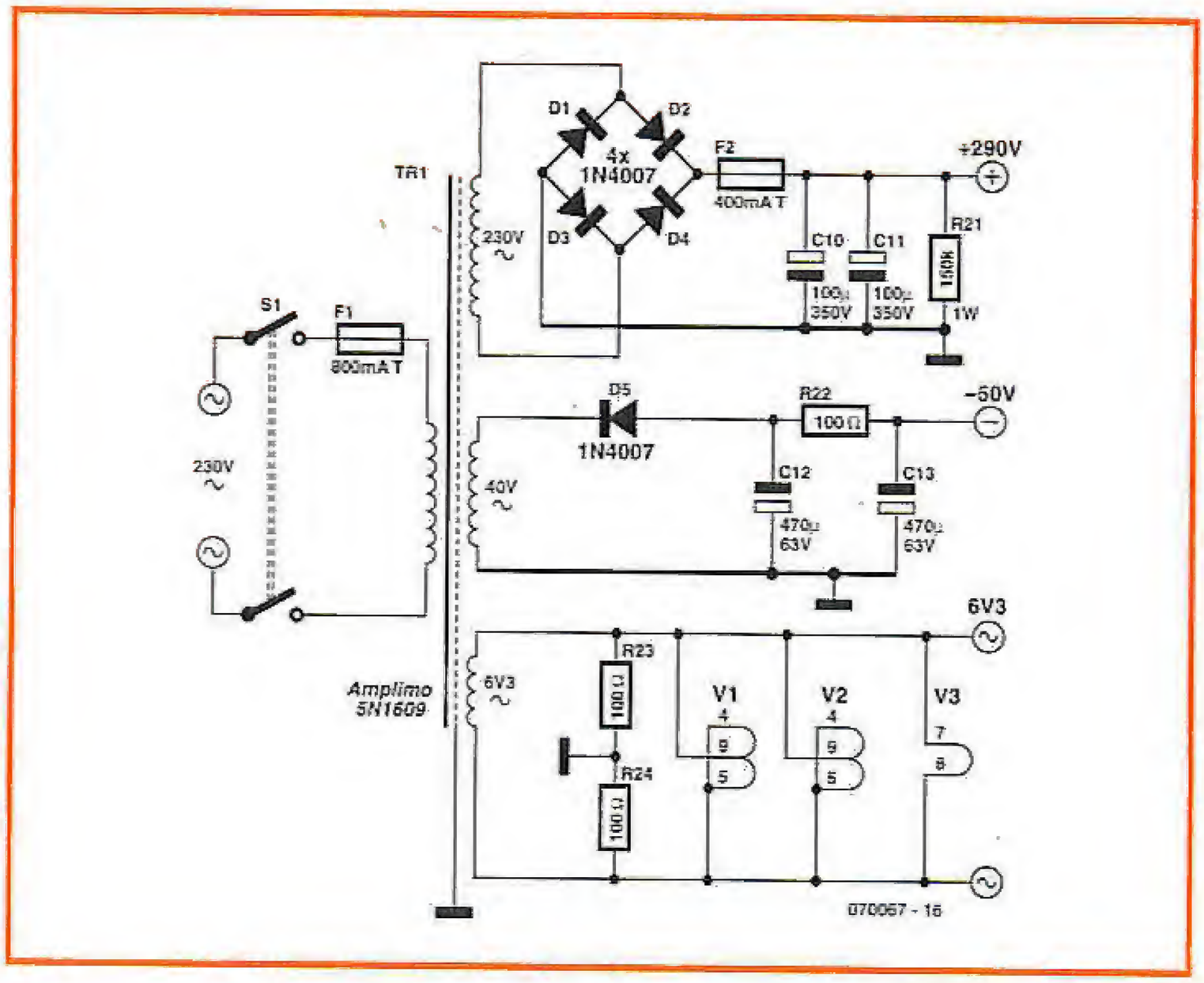

Figure 6. The power supply uses a special mains transformer which is available from Amplimo.

for the triode push-pull amplifier. The power supply is shown separately in Figure 6.

The cost of the output valves and output transformers often make the most significant contribution towards the final price tag of a valve power amplifier. For this design we chose the 6AS7 valve in combination with the 3A524 output transformer. The 6AS7 is a high quality valve for a relatively low amount of money (for details and pricing refer to www.amplimo.nl). The 6AS7 is a dual power triode (maximum dissipation 2×13 W) which was originally designed to be the series-pass element in regulated high-voltage power supplies. This can be seen from the maximum allowable value for the voltage between the cathode and the filament (±300 V). This indicates high quality isolation. The remaining properties of the 6AS7 are comparable to those of other power triodes. The 3A524 output transformer (maximum 40 W) is generously sized for a 9-watt amplifier. The primary impedance is 3545 Ω. For optimal output drive the DC settings for the output valves are:

U_a = 270 V, I_a = 67 mA, U_k = 80 V and R_k = 1k2.

Triode push-pull output stages have, by their very nature, a class-A characteristic operates as discussed below.

Suppose that, because of the drive signal, the anode current of V3a increases significantly, U_a of V3a will then reduce significantly. The influence of V3a on the output transformer is now dominant and this causes an increase in U_a of V3b. Since the U_a of triodes has a large effect on anode current, V3b does not stop conducting despite the increase of U_g (more negative), which results in a class-A operation of the output stage.

The 'quiescent current' of about 10 mA has very little effect on the efficiency. Because of this class-A behaviour 'crossover distortion' is precluded and the current consumption from the power supply is almost independent of the output drive.

The preamplifier (V2) has to be able to deliver two drive voltages of up to 70 V_{AC} to the output stage and that places high demands on the dynamic range. An ECC82 (12AU7) is very appropriate for this. To obtain the highest possible drive voltage, R7, R8 and R9 are connected to –50 V instead of ground. This increases the power supply voltage to V2 by 50 V to 320 V.

A 'hybrid DC bias setting' was selected here. R9 is a common cathode resistor (automatic negative grid adjustment). The voltage across R9 is partially determined by the current through R10. The consequence of this is that the DC bias setting is a hybrid of automatic and fixed-negative, which results in better drive capabilities. Because V2 is a push-pull circuit of triodes as well, the distortion is also small because of the cancellation of the even order harmonics.

The DC bias setting combined with the values of R11 and R12 ensures that sufficient capacitive current can be delivered to the output stage at higher frequencies. The input capacitance of V3a and

components list

Resistors (all metal film 1%, 0.25W or 0.6W unless otherwise specified)
R1 = 470kΩ
R2 = 390Ω
R3 = 8kΩ2
R4,R5 = 100kΩ 1W
R6 = 33kΩ
R7,R8 = 470kΩ
R9 = 470Ω
R10 = 4kΩ7
R11,R12 = 22kΩ 1W
R13,R14 = 470kΩ
R15,R16 = 1kΩ
R17,R18 = 1kΩ2 6W (wire wound) (1)
R19 = 33kΩ 1W
R20 = 150Ω 5W (wire wound)
R21 = 150kΩ 1W
R22,R23,R24 = 100Ω
P1 = 50kΩ logarithmic law potentiometer

Capacitors
C1 = 150pF ceramic
C2-C5 = 33nF 400V
C6,C7 = 47µF 100V electrolytic
C8 = 10µF 350V electrolytic
C9,C10,C11 = 100µF 350V electrolytic
C12,C13 = 470µF 63V electrolytic

Valves
V1 = 12AX7 or ECC83
V2 = 12AU7 or ECC82
V3 = 6AS7

Semiconductors:
D1-D4 = 1N4007 or bridge rectifier 400V piv @ 1A
D5 = 1N4007

Miscellaneous
Tr1 = mains transformer type 5N1609, primary 230 V, secondary 230V/40V/6.3 V (www.amplimo.nl)
Tr2 = output transformer type 3A524 (www.amplimo.nl)
F1 = fuse, 600mA, slow
F2 = fuse, 300mA, slow
Aluminium corner profile, e.g. # 04.90.2208 (www.tessatronic.nl; www.display.nl)
Self adhesive standoff, e.g., Conrad Electronics # 532037-89
Self adhesive mounting for cable strap, e.g., Conrad Electronics # 543234-89

(1) matching desirable

V3b amounts to about 40 pF.
For the phase shifter an ECC83 (12AX7) is the most suitable, in particular because of its relatively high μ, the gain of the first stage is as high as possible. The influence of R6 on the offset (the non-ideal current source functionality is of concern here) is about 4%. Further improvement by increasing the negative power supply voltage and a larger value for R6 is not worthwhile.
The input signal for the amplifier is connected to V1b and the negative feedback signal, via a switch and R3||C1 and R2, to V1a. Swapping the input terminals results in positive feedback, which causes the amplifier to oscillate badly. It is therefore very important to carefully check the numbering on the valves and the colour codes of the output transformer.
Because of the good open-loop characteristics, a moderate negative feedback factor of 3 (9.5 dB) was selected. The negative feedback can be switched on and off to be able to determine the difference in listening tests. When the negative feedback is switched on, the input signal needs to be larger by a factor of 3 (600 mV instead of 200 mV for an output power of 9 W).
It is important to consider that with valve amplifiers, large negative feedback can cause RF instability in addition to AF instability. Because of the AF phase shift resulting from the RC coupling between stages and the output transformer, a very low frequency oscillation can occur. In the past, this has sometimes been called 'motor-boating'. Resistors R15 and R16, the so-called 'grid stoppers' reduce the risk of RF instability in the output stage.

The power supply

The power supply section can be seen in Figure 6. The power supply transformer, with the part number 5N1609, has been specifically designed by Amplimo Netherlands for this project, and is available from them (www.amplimo.nl). The electrostatic shield has to be connected to the chassis and its task is to divert mains borne disturbances to earth that could otherwise be capacitively coupled through the transformer to the power supply.
Triodes make high demands on the power supply ripple filter. The design of these filters is based on a so-called π-network, such as C10||C11, R20 and C9. The series resistor has a comparable effect to that of the forward resistance of a valve rectifier. This forms a low-pass filter which effectively suppresses the ripple voltage (the higher harmonics in particular), mains disturbances that are inductively coupled through the transformer and switching pulses from the rectifier diodes. Since the amplifier (including the output stages) operates in class-A, the current consumption from the power supply is practically constant and the use of series resistors is not a problem.
In order to limit the hum from the filament supply, the 'electrical centre' of the filaments is connected to ground via R23 and R24.
Under certain circumstances, when, for example, the amplifier is switched off shortly after is has been switched on, it is possible that the high voltage electrolytic capacitors in the power supply filter can take a very long time to discharge completely. This is undesirable, particularly from a safety perspective. Connecting a 'bleeder' resistor (R21) in parallel with C10 and C11 discharges the electrolytic capacitors to less than 50 V_{DC} in about two minutes.

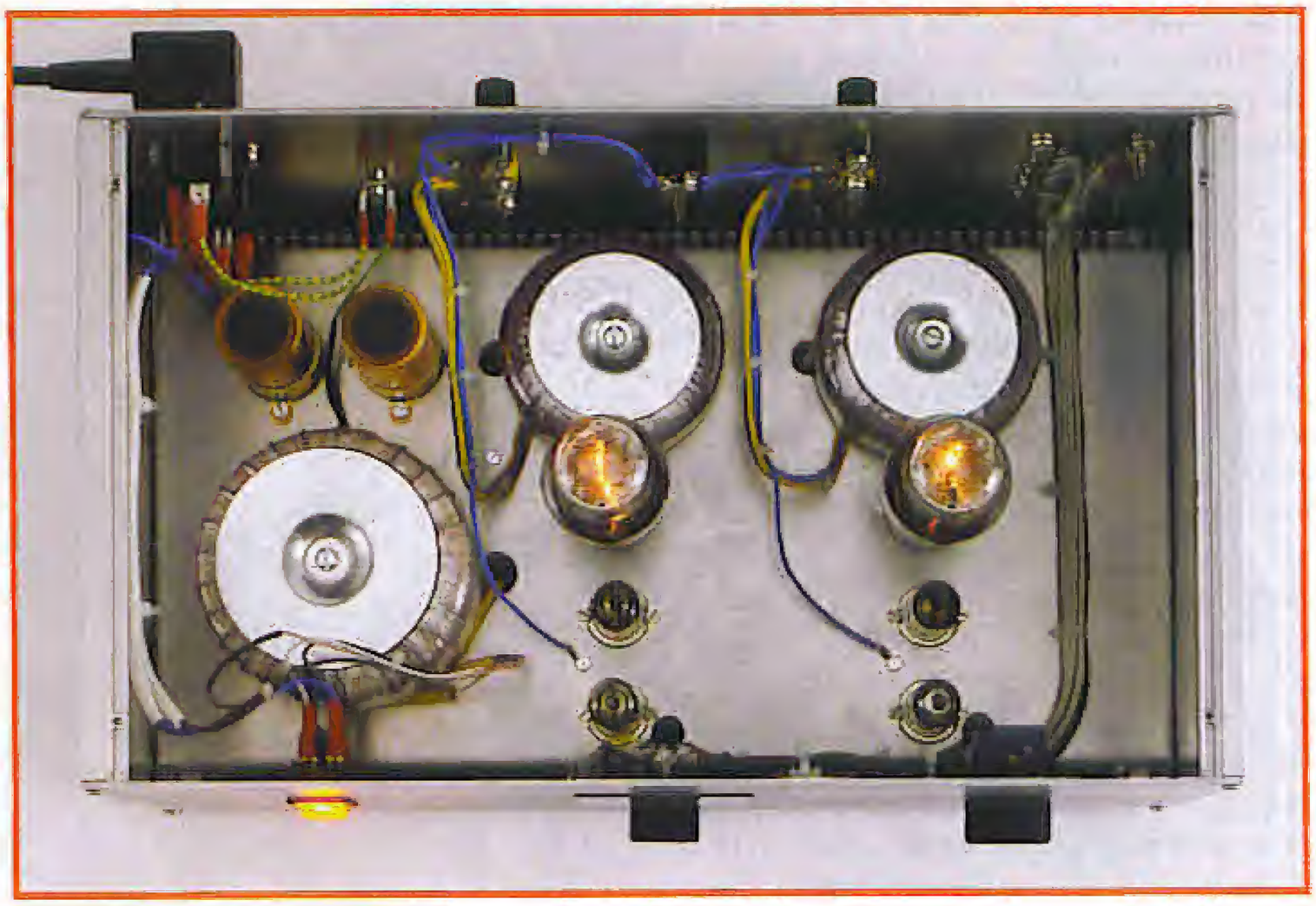

Figure 7. The amplifier viewed from above.

Realisation

The starting point for the construction

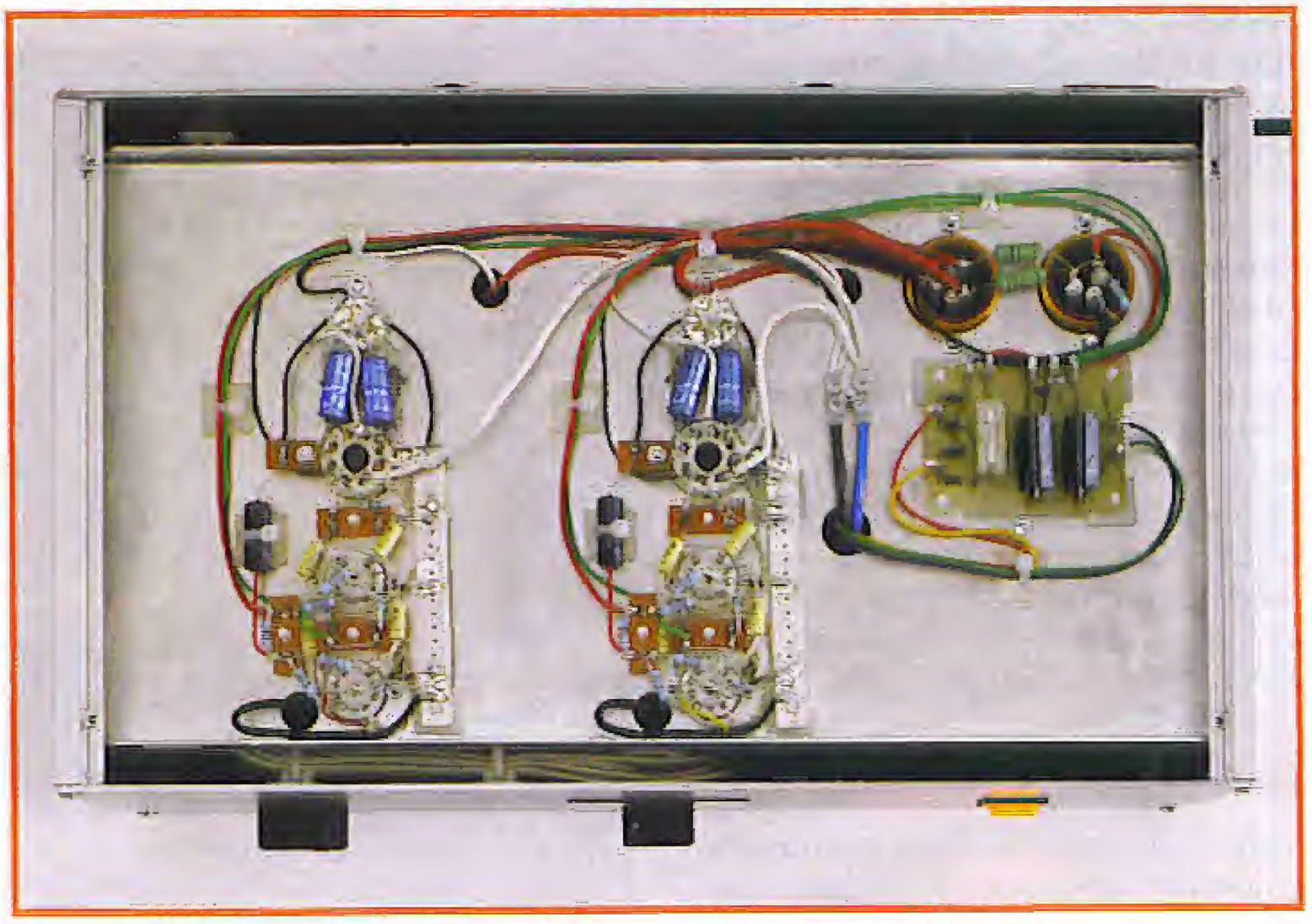

Figure 8. This is how the components are mounted on the bottom side.

of the enclosure (Figures 7 and 8) is an aluminium corner profile (for example type 04.90.2208, available from Tessatronics, Display and others). The profile is normally supplied in a length of 1 m and can be used for four corner profiles of 25 cm each. The front and rear panels are made from 3-mm thick hard aluminium sheet and are attached to the ends of the corner profiles with M5 bolts. The side panels (1.5 mm thick aluminium sheet) fit in the slots of the corner profiles. These side panels support the chassis plate (2 mm thick aluminium plate with 4 cornered edges) with M5 nuts and bolts. Between the chassis and the front and rear panels is a gap of 15 mm to ensure sufficient cooling. The top and bottom plates (perforated steel plate, 1 mm thick, with cornered front and rear edges) is attached with M3 bolts and square nuts that fit in the corner profile.

The connecting and the mounting of the components is done using the 'hard-wired' method. This takes a little bit more time compared to assembling a printed circuit board, but that shpild not be an objection considering the simplicity of the circuit. An added benefit is that the results are better, among other things because twisted wiring for the filaments has a lower risk of hum and is better suited to handle large currents. The assembly (see Figure 8) uses discs cut from circuit board for the star-point ground, strips of circuit board for ground and cable supports. The discs, strips and cable supports are attached to the chassis with self-adhesive stand-offs. There are two options regarding the coupling capacitors C2 to C5: cheaper polyester foil from, for example, ERO or high-quality paper-in-oil from Jensen.

It is recommended to use 1 W/1% metal film resistors for anode resistors R4, R5, R11 and R12. That is because the larger dimensions of these resistors are better suited for dealing with high voltages.

Since this amplifier is implemented as a 'complete amplifier', the front panel has a power switch, input selector switch and a volume control. On the back of the enclosure you can add, in addition to the usual inputs and outputs, the switch for turning the negative feedback on and off, so that it becomes very easy to experiment with this.

Test results

With valve amplifiers it is customary to give the maximum output power at THD = 5%. Because this amplifier can also be used open-loop we assumed a value of 2%. This value also corresponds to the limit before clipping occurs.

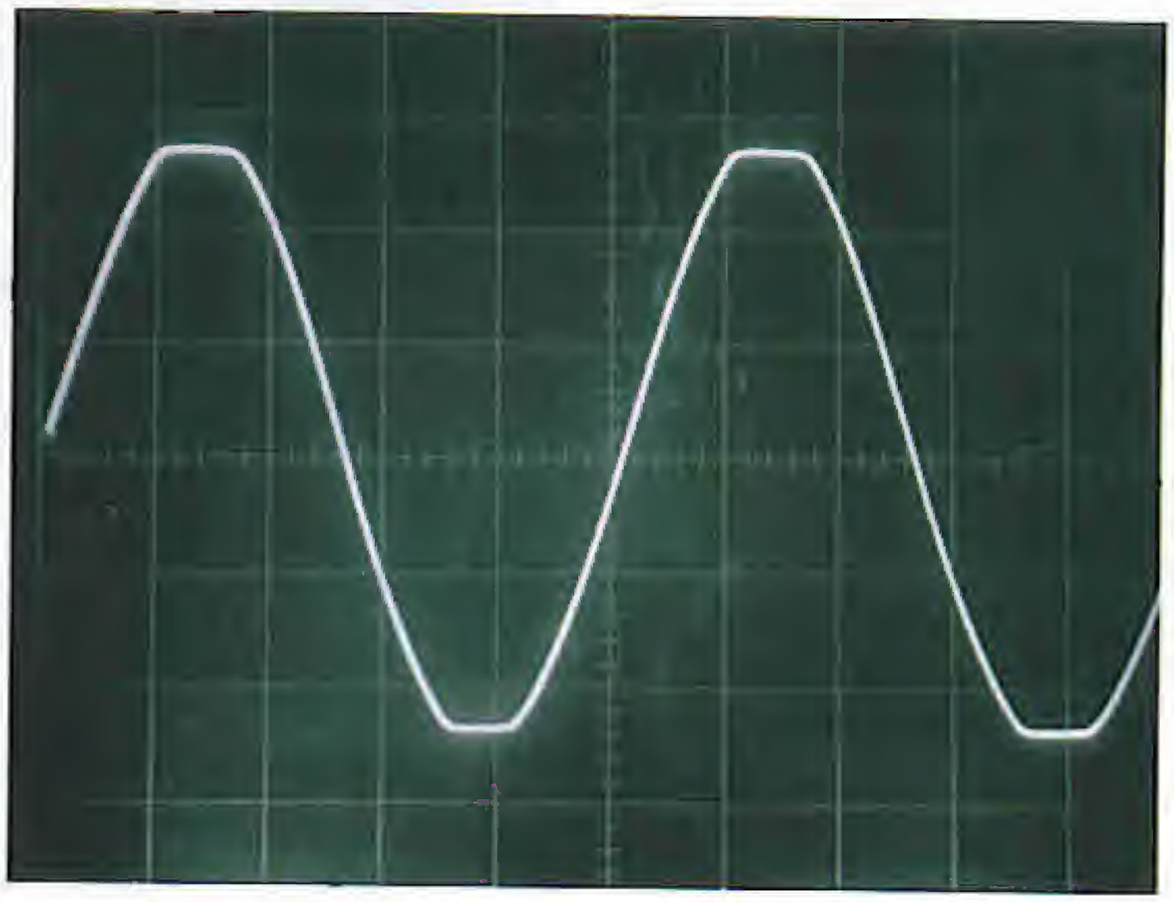

Figure 9. Clipping behaviour at 11 W/1 kHz (5 V/div.).

Figure 9 shows the soft-clipping behaviour at an output power of 11 W (5 V/div.). Figure 10 shows the open-loop square-wave response at 2 kHz and 5 V/div.

It is of interest to note that this amplifier, because of the characteristics of the triode output stage, is open-loop stable.

(070067-I)

Literature

[1] Lecture Notes on Electronics, Technical University Delft, 1957.

[2] Audio Frequency Amplifier Design, E. Rodenhuis, 1959 (reprinted by Audio Amateur Press, 1994)

[3] Electron Tube Handbook, Volume 1, Philips, 1964.

[4] Audio Power Design Handbook, Douglas Self, page 9.

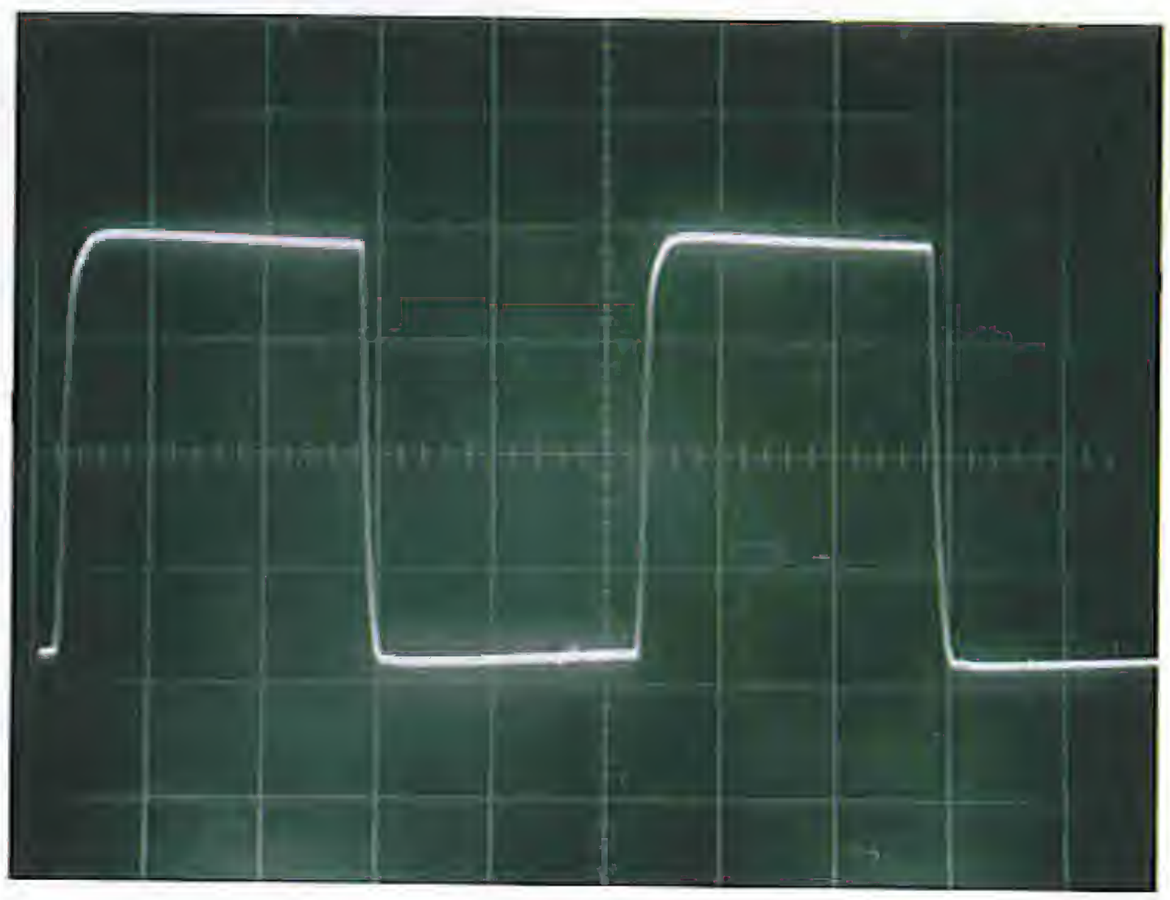

Figure 10. Square-wave response without feedback (2 kHz, 5 V/div.).

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Stand Alone OBD-II

Interpret 'trouble codes' without a PC

Folker Stange and Erwin Reuss

This handy analyser makes a simple job of rummaging through the information stored by the client–accessible part of your car's computer. It works with all current OBD-2 protocols and can read and erase trouble codes stored in the vehicle and reset the MIL display. All this without the help of a PC or a visit to a service station.

Since the turn of the millennium more and more new car models have been fitted with the latest version of the on board diagnostic interface OBD-2. With the increasing sophistication of modern engine management many new owners have seen the benefits of an OBD analyser such that it is fast becoming an essential part of the garage tool kit along with the torque wrench and spark plug spanner.

It has been reported that sometimes when owners fit a new car radio or satnav system to their car the vehicle management system unnecessarily registers a fault, similarly some owners who have modified the engine to accept an alternative fuel have noticed that the engine management can incorrectly interpret the engine condition and trigger an error. In some cases the engine management can even be switched into an emergency condition. Whatever the cause the outcome is the same; a dashboard mounted MIL (malfunction indicator light) comes on, a fault condition is stored and it is necessary to make an (expensive) visit to the nearest garage to have the 'trouble' put right and the MIL reset. With the OBD analyser described here in your glove box it is a simple job to connect to the OBD socket, find out what the trouble is, reset the error and continue on your journey. On cost grounds alone the price of the analyser will be more than repaid by avoiding just a single unnecessary visit to a dealership garage.

A number of OBD analysers have been featured in the electronics press (including *Elektor Electronics*) describing an interface between the OBD connector and a laptop. The approach we have adopted here is however far less cumbersome, this stand-alone unit does not require a notebook or battery, recognises all the usual OBD-2 or EOBD protocols and is small enough to stow in your car's glove box. Operation is quite straightforward using just two buttons, 580 of the commonest trouble codes can be recognised and described on its running text display.

The Circuit

The OBD-2 analyser employs an AT-90CAN128 microcontroller from the ATmega128 family from Atmel. This par-

2 Analyser

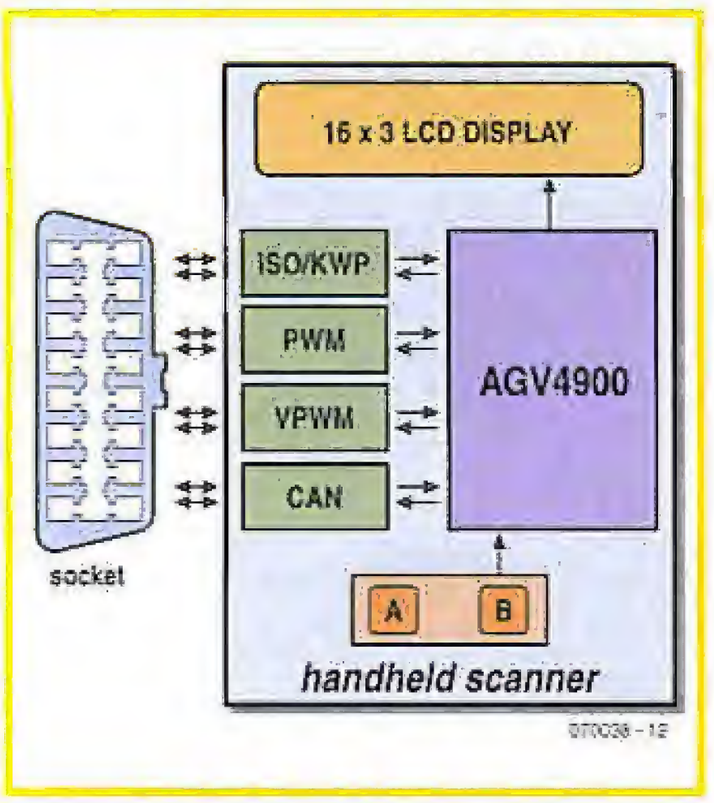


Figure 1. Block diagram of the OBD-2 analyser.

ticular model has an on-board CAN bus interface as shown in **Figure 1**. The controller is supplied pre-programmed with the AGV4900 firmware which handles the user-interface including push buttons, buzzer, LEDs and LCD.

Pin assignments the OBD-2 connector are given in **Figure 2**. In order to support all the current OBD-2 protocols the analyser needs to be able to interface to several bi-directional interfaces:

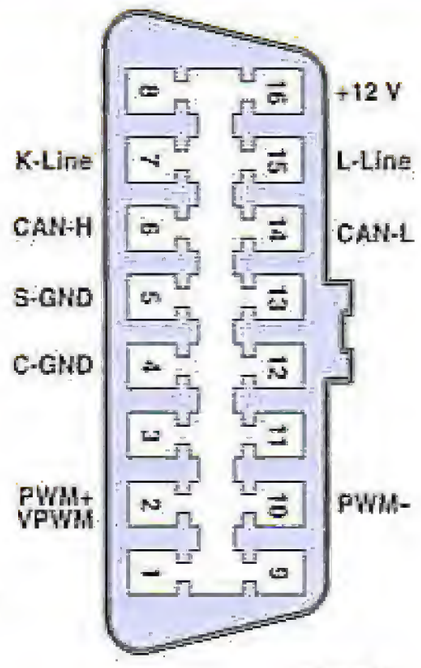


Figure 2. Pin definitions of the OBD-2/EOBD connector.

- K/L interface
- PWM interface
- VPWM interface
- CAN interface

The first three of these in the circuit diagram (**Figure 3**) have been implemented using transistors and comparators configured to meet the interface standards. The specified pull up resistors for the K and L signals have a rela-

Specification

- Automatic or manual selection of OBD-2 protocol
- Very fast automatic protocol scan (0.1 to 2.6 s per protocol)
- Fast software boot sequence (ready to go around a second after switch on)
- Read and display important vehicle information (depending on the vehicle)
- Real-time sensor reading (selectable)
- Vehicle chassis number display (if supported by the vehicle manufacturer)
- Readout and display of the trouble code memory
- Read out and display of Freeze-Frame data
- Erasure of trouble code memory
- Language selection (English or French)
- 580 trouble codes with description in running text
- All existing OBD protocols for private vehicles are supported:
  ISO9141-2
  ISO14230-4 (KWP2000)
  J1850 PWM
  J1850 VPWM
  ISO15765-4 (CAN, 11/29 Bit, 250/500 kbits/s)
- Power for the analyser is supplied from the vehicle's OBD-2 connector (12 V)
- Backlit 3-line LC display with adjustable contrast
- Acoustic signal gives audible feedback and beeps when trouble codes recognised
- LED Indicators for connection status and data traffic flow
- Simple operation using just two push buttons
- Connection for a standard OBD-2 cable
- Handheld format: 80x135x30 mm (wxhxd), weight 150 g (approx.)
- Supplied as a kit through Elektor SHOP

Points to note

The OBD analyser is only suitable for vehicles fitted with an OBD-2/EOBD connector.

EOBD is fitted to vehicles sold in the EU:

- after 01.01.2001, for petrol engine vehicles.
- after 01.01.2004, for diesel engine vehicles.

Before the analyser is plugged into any vehicle manufactured before these dates, it is important to check compatibility with the OBD-2 standard. The website of Florian Schäffer [3] contains a databank of vehicles where you check to see if yours is OBD-2 compatible.

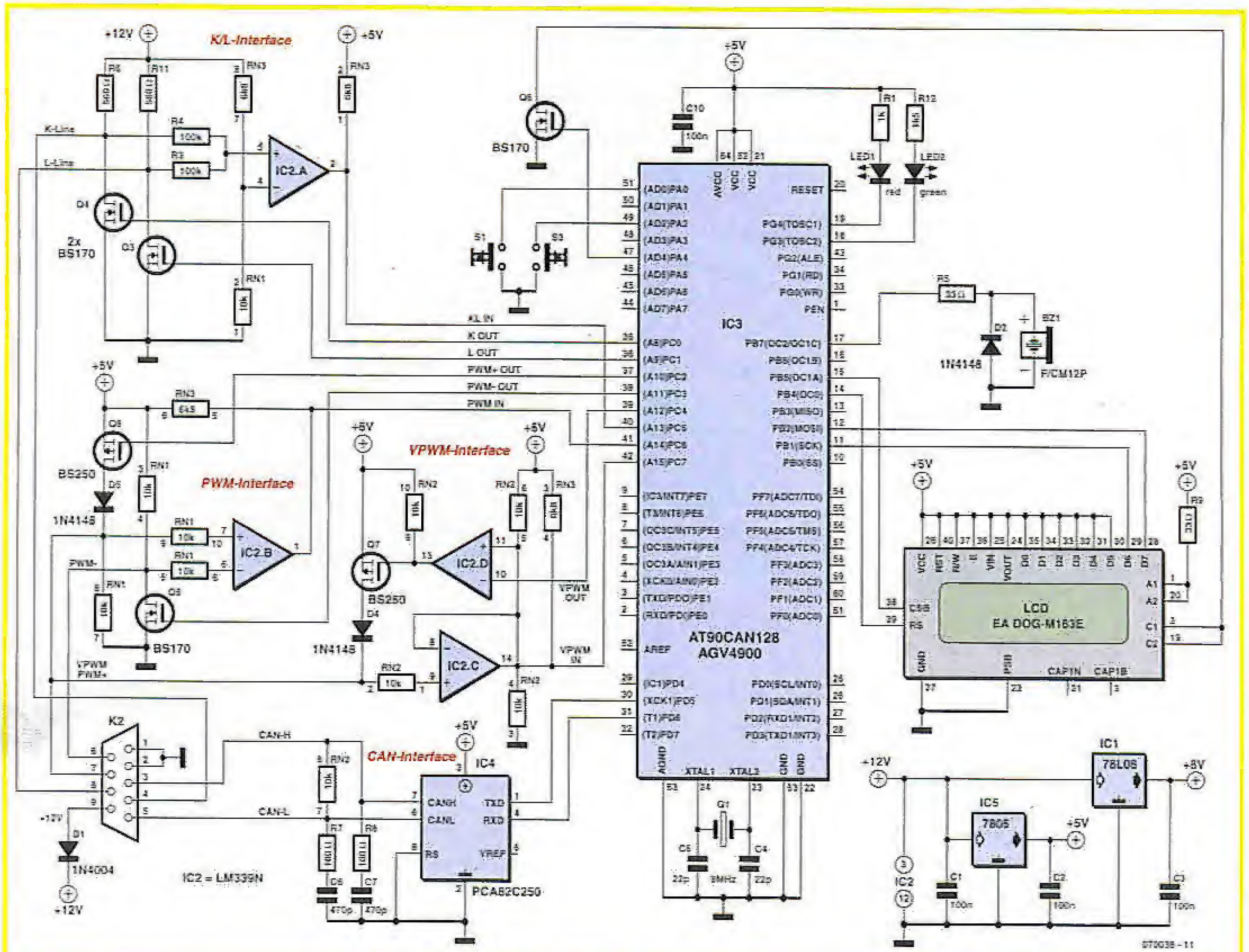


Figure 3. The AVR microcontroller with on-board CAN interface is the main part of the circuit diagram.

tively low impedance so MOSFETs have been used here as drivers. The CAN bus driver IC type PCA82C250 takes care of the CAN interface.

The user-interface software is logically designed such that just two push buttons are required to operate the analyser and select all possible menu options. Connections for the buzzer, the 'connect' and 'Data Traffic' LEDs should not require any further explanation. Control of the three-line LCD is a little more complex, a five wire SPI interface connects the display to the controller. LED backlights ensure that the display is night time readable. The relatively low controller clock speed (8 MHz) is a good compromise, producing a low level of EMI emissions while still giving ample operating speed for this application.

The Firmware

The heart of the OBD-2 analyser is the pre-programmed microcontroller with the designation AGV4900 [1] available solely from Stange Distribution [2]. The software was developed by co-author Erwin Reuss. Like similar OBD projects the firmware for this analyser is only available pre-programmed into the microcontroller where it is copy protected. The source files are not available for download. Without this software copy protection is would not be possible to offer the analyser in kit form. There is no possibility for the home constructor to assemble a low-cost version of this design unless of course all the necessary software is written from scratch.

A menu option switches all display information between either English or French (for the convenience of our Canadian readers). Stange Distribution are specialists in OBD related equipment and produce several OBD-2 controllers for applications in the field of OBD development.

All the OBD analyser functions can be selected from the menu using just two keys. One feature of the software is the very quick boot procedure which ensures that the device is ready for use in little more than a second after switch-on. The most important 580 trouble codes have a plain text description of the fault which is displayed in running text (in the language chosen). This feature helps promote a quick and effective diagnosis of the problem. In the vast majority of cases there will be no need to look up the code in an OBD trouble code book.

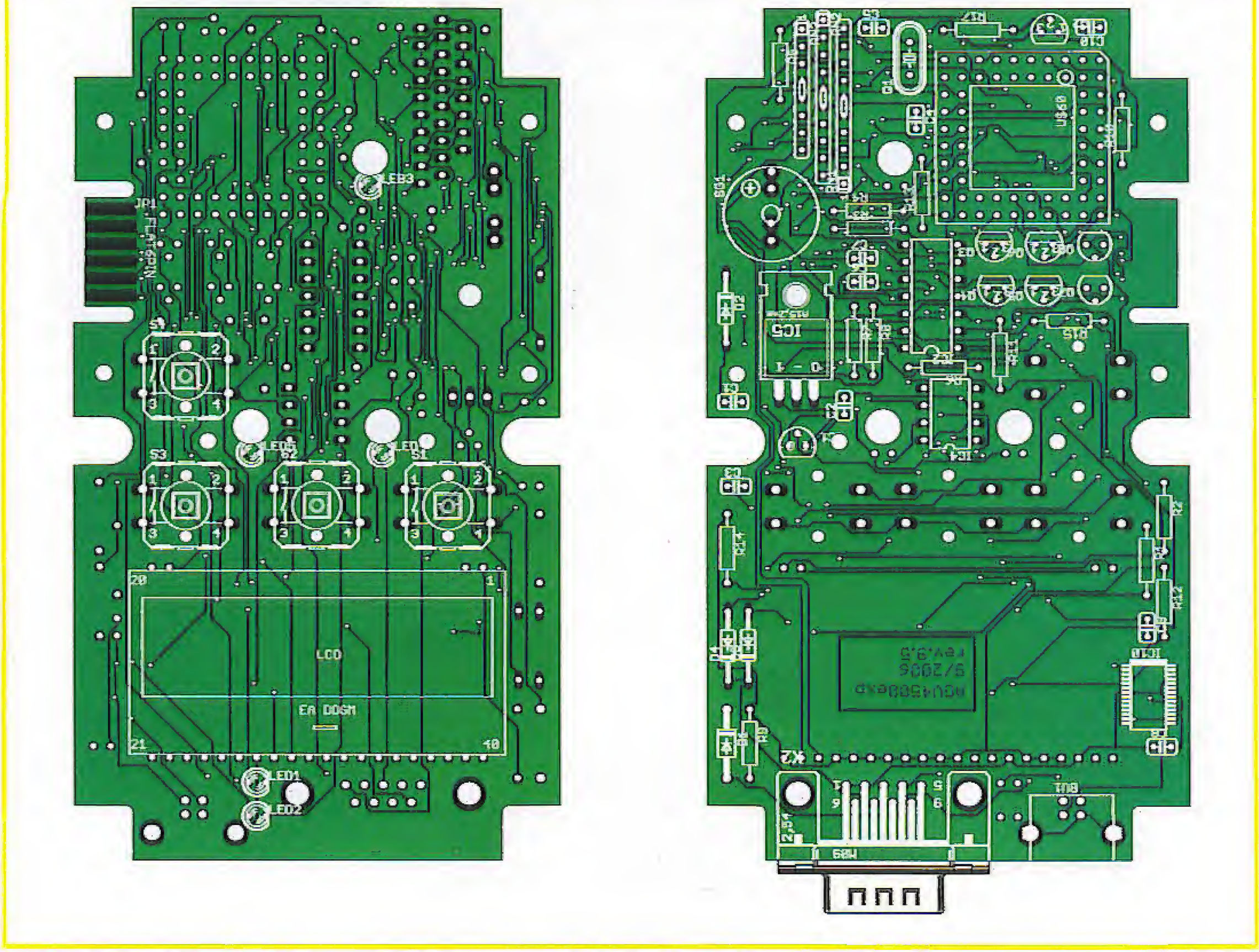


Figure 4. The PCB is an SMD-free zone.

Putting all the bits together

Attention has been paid to the PCB layout (**Figure 4**); SMD components have not been used for this design to simplify component mounting. The PCB is produced to industry standard using FR4 type board with gold plating. Gold is chemically inert and gives the board almost unlimited shelf life. The plating also ensures that there should be no problems of corrosion which have been reported when lead-

COMPONENTS LIST

Resistors

RR1 = 1kΩ
R3,R4 = 100kΩ
R5,R9 = 33Ω
R6,R11 = 560Ω
R7,R8 = 100Ω
R12 = 1kΩ5
RN1,RN2 = 10kΩ SIL-10 array
RN3 = 6kΩ8 SIL-8 array

Capacitors

C1,C2,C3,C10 = 100nF
C4,C5 = 22pF
C6,C7 = 470pF

Semiconductors

D1 = 1N4004
D2,D4,D5 = 1N4148
IC1 = 78L08
IC2 = LM339N
IC3 = AT90CAN128 (Atmel; QIL case), programmed as "AGV4900" (Stange Distribution)
IC4 = PCA82C250 (Philips)
IC5 = 7805
LED1 = 3mm, red
LED2 = 3mm, green
Q3-Q6 = BS170 (TO92)
Q7,Q8 = BS250 (TO92)

Miscellaneous

Q1 = 8MHz quartz crystal (HC49/S)
LC-Display 3x16 lines, type EA DOGM163E; with background light: EA LED55X31-A
S1,S3 = PCB mount pushbutton type 40-XX B3F (Omron) with matching aluminium cap
DC buzzer
X2 = 9-way sub-D plug (male), PCB mount
IC socket 14-way
IC socket 8-way
QIL socket (4 segments of 16 pins)
PCB
Case with front panel foil
Mounting materials

Note: Kit of parts no. 070038-71 contains all components, the case (with front panel foil fitted), mounting materials and OBD-2 cable, see Elekior SHOP advert or www.elekior-electronics.co.uk

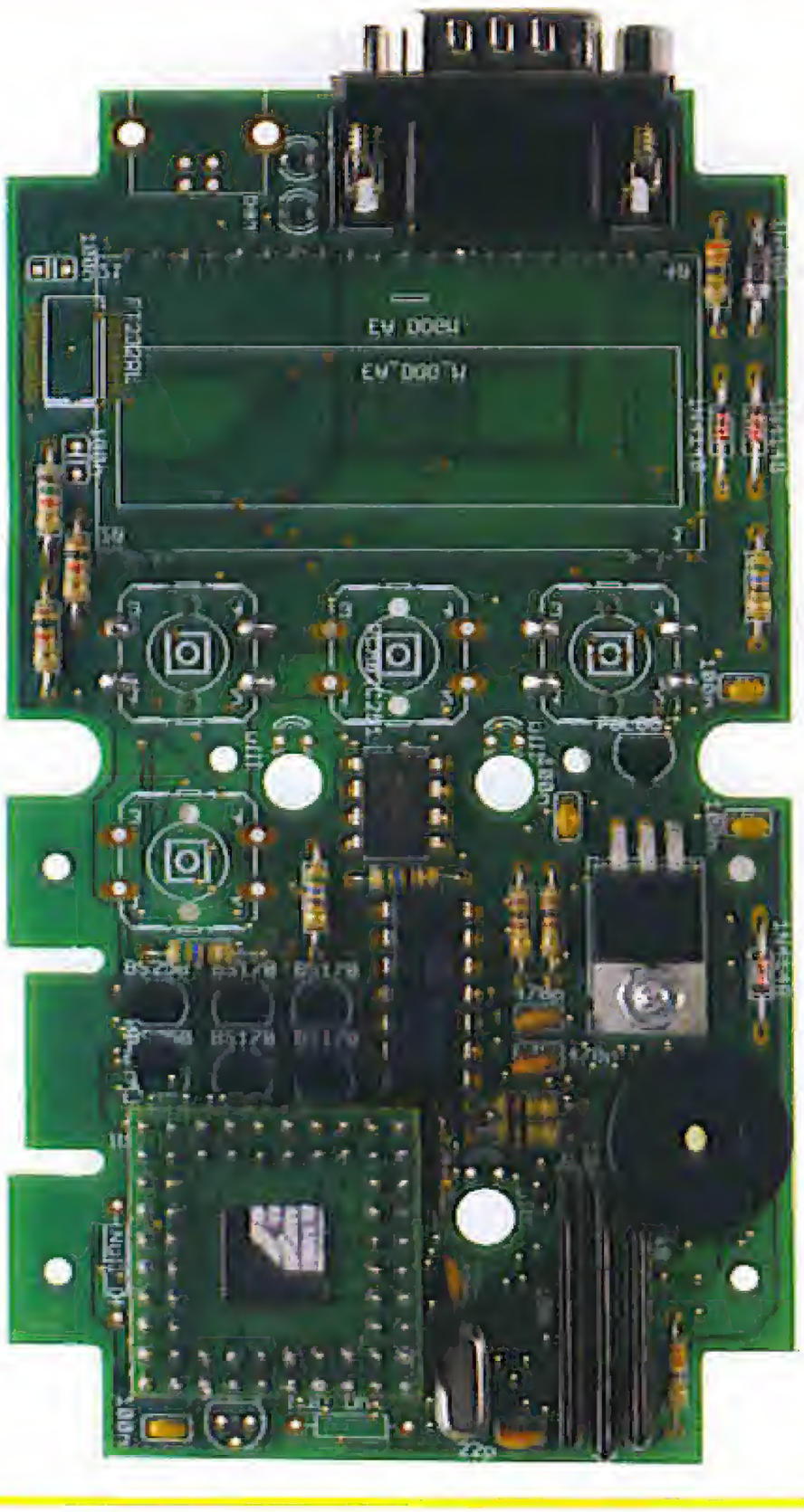


Figure 5. The PCB component side.

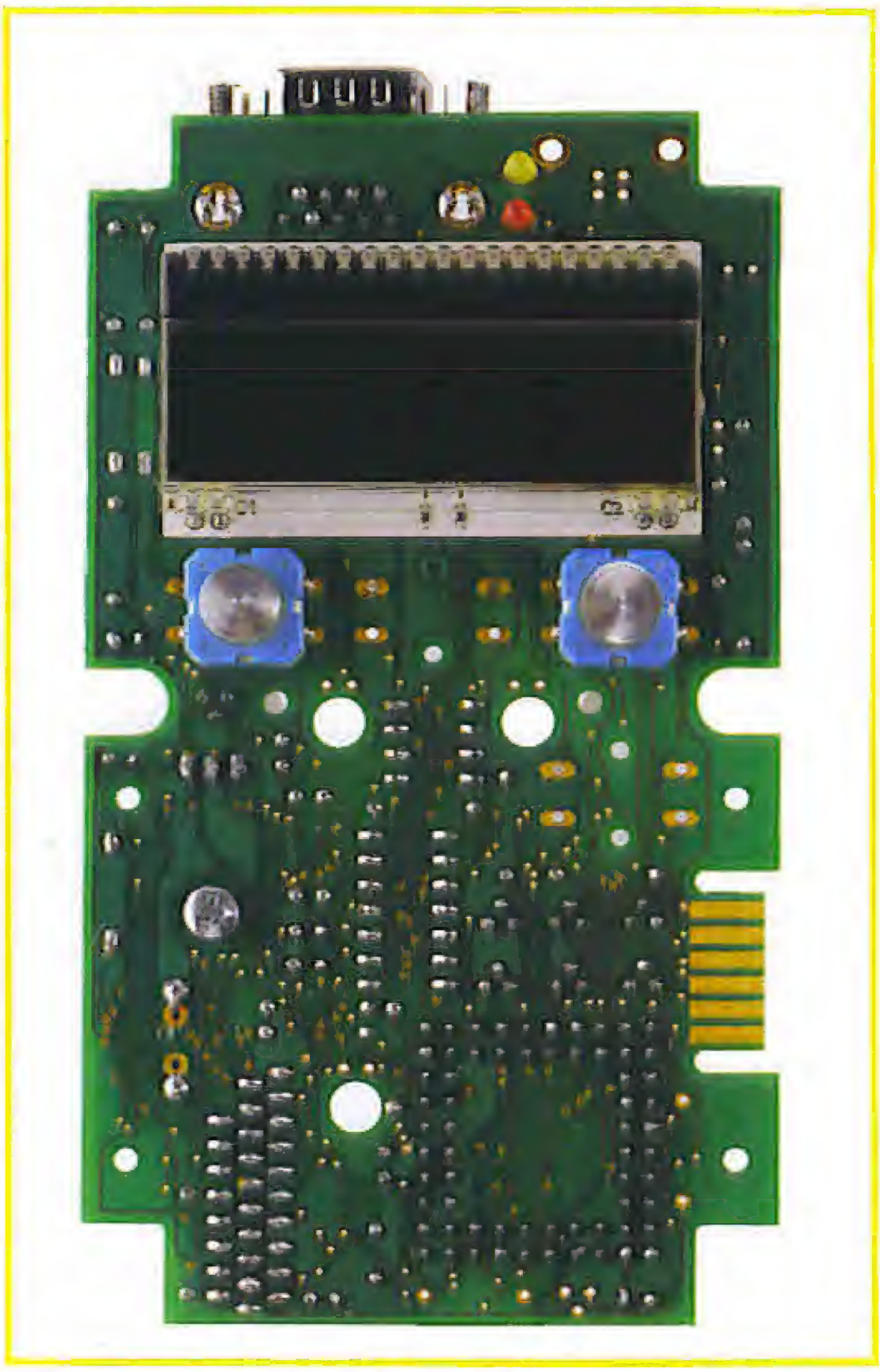


Figure 6. The two push buttons, LEDs and LCD are mounted on the other side of the PCB.

free solder is used on unplated boards. Gold has excellent tinning properties and allows the use of either lead-free or lead/tin solder. Apart from the need to take care with component placement and soldering, no special electronic skills or programming competence is needed to complete this project.

Except for the two LEDs 'connect' and 'data-traffic', the two pushbuttons and the LC display all other components are mounted on the PCB side printed with the component outlines and identification (**Figure 5**). Mounting the component starts with soldering each of the individual resistors into place followed by the diodes, capacitors, crystal, IC sockets, resistor networks (make sure they are the right way round), voltage regulator and then the transistors. The 7805 should first be mechanically secured before the leads are soldered in place. Once the buzzer and the sub-D connector are fitted the board can be flipped over and the pushbuttons, display and LEDs soldered into place.

The AT90CAN128 chip from Atmel used in this project is unfortunately only available in either the TQFP or MLF/QFN outline and neither of these are really suitable for a self-build project. The controller is therefore supplied (in MLF outline) already mounted on a small carrier board. It is only necessary to fit an intermediate pin/socket arrangement to connect the carrier board to the main PCB. The pin layout of this connector is the same as a OIL64 package (Quad in line, 64 Pins). All the components for this connector are included in the kit, to ensure success it will be necessary to follow the instructions carefully, a mistake here will be difficult to correct.

The complete socket is made up of four strips (**Figure 7**) fitted to the main PCB, each strip is fixed in place initially by soldering just one pin of each of the strips, this allows the final layout of the complete socket to be easily adjusted until it exactly matches the layout.

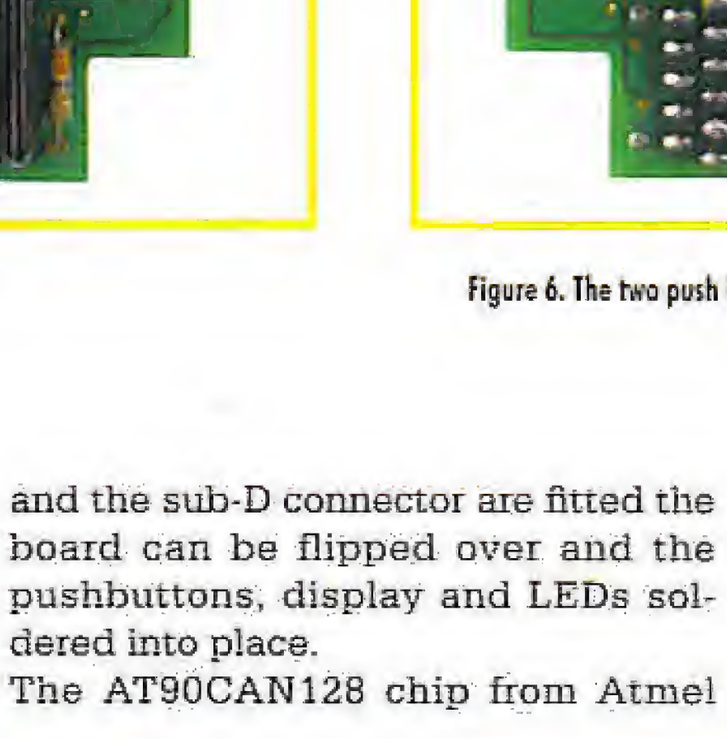


Figure 7. The controller board connector is made up of four sections.

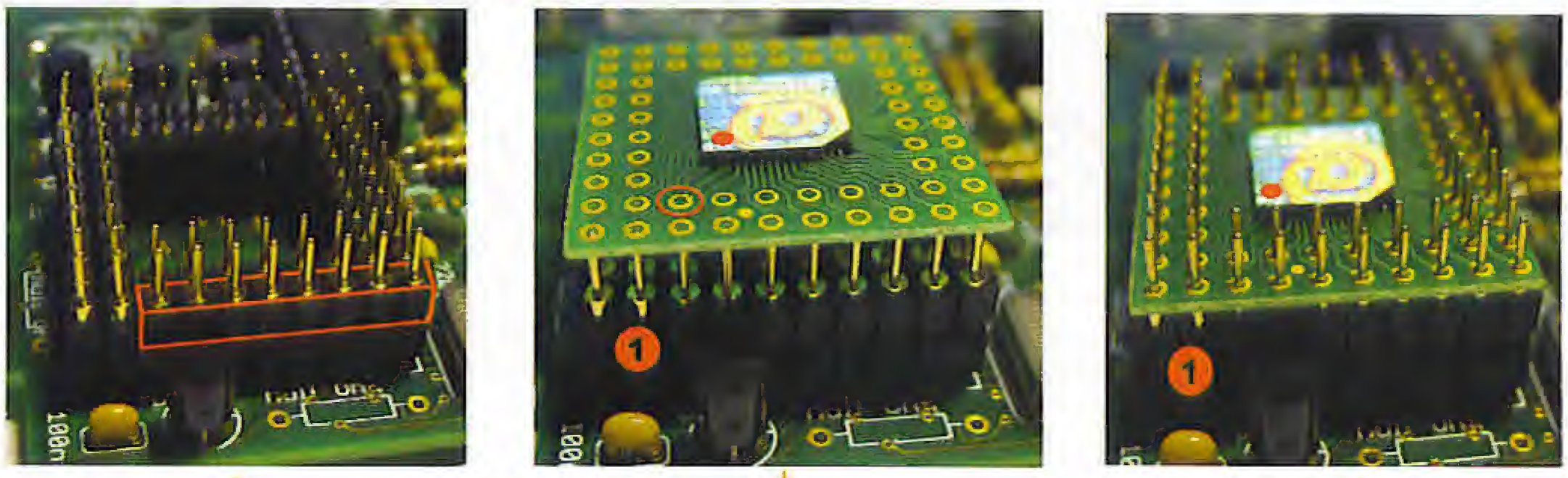


Figure 8. The three steps to mount the controller board.

Once you are sure that the four strips are accurately aligned (check that they are also all at the same height on the board) all the remaining pins can be carefully soldered to complete the socket.

The carrier board can now be fitted with the pins. The supplied pin strips must be carefully separated into 8-pin lengths. Any rough corners can be smoothed down with a fine file. The strips are pushed fully into the socket **Figure 8a** (They only fit one way round: the thinner tapered pins go into the socket).

The controller board can now be positioned onto the pins (**Figure 8b**) ensuring that pin 1 is correctly aligned (to the left by C10). The 64 pins can now be carefully soldered onto the controller board (**Figure 8c**).

Once all the components have been fitted a short test can be carried out by connecting a 12-V supply to the sub-D connector (pin 9 = +12 V, pin 1 or 2 = 0 V). The current drawn by the analyser should not exceed about 150 mA. The display backlight will be lit and the boot loader version number will appear on the display followed by the greeting message. The short self-test is now complete.

The finished PCB can now be mounted in the case: Fit the pushbutton caps and the sub-D cover, remove the protective film from the display and with the display facing downwards position the PCB into the front cover of the case. The small countersunk screws can now be carefully screwed in and tightened. Lastly, fit the remaining half of the case and the OBD-2-Analyser is now ready for action!

Figure 9. Displays: (a) Contrast setting, (b) Start menu, (c) Status display, (d) MIL/DTC PID Menu, (e) DTC trouble code number.

Analyser operation

The first requirement before the OBD-2 analyser can be used is that the car is fitted with the corresponding OBD-2 connector (see the advice given in 'points to note' elsewhere in this article). If it is, the supplied OBD-2 cable is inserted into the OBD-2 connector in the car. The connector shouldn't be too difficult to locate, regulations insist that it must be mounted in the vehicle within 1 metre of the driver's seat. A concise operating manual for the analyser is available to download from www.elektor-electronics.co.uk. A shortform manual is also supplied in the kit of parts so we will not delve too deeply into the finer points here. An online simulator is also available on our website so you can familiarise yourself 'virtually' with the analyser operation.

At switch-on it is possible to alter the display contrast (**Figure 9a**). This is achieved by holding down keys A and B and plugging the analyser into the OBD-2 socket. The contrast changes each time key A is pressed. Once you are happy with the setting release key A and press B to store it. This basic method is used to control the analyser: Key A cycles you through the menu options while key B confirms a selection or provides a response from the equipment.

The display now shows the greeting 'ELEKTOR OBD2 1.4' with the start menu (**Figure 9b**) following shortly after-

Figure 10. Trouble code menu showing a description of the trouble in running text.

Figure 11. The Freeze frame menu (PID select).

wards with the options: *Start Diag*, *Protocol* and *Language*. When the analyser is regularly used on the same vehicle and you are sure of the correct protocol then it can be selected otherwise option code 0 tells the analyser to automatically find the correct protocol. A press on key B begins the scan (if the vehicle interface is not compatible with OBD protocol the test ends with a failure message). When the scan has run the display will show the state of the MIL/DTC indicating if any troubles were present (**Figure 9c**). Selecting the option *Live Data* with button B will show the actual value of a parameter. The chassis number or *vehicle ID* can be read and the communication *Protocol* displayed as well as the option to rescan.

The current reading of a sensor (*live data*) is given in the PID (parameter identifier) menu. The example shown in **Figure 9d** is a reading of the intake Mass Air Flow (MAF in g/s). Pressing key B takes you back to the previous menu. When a failure has been detected by the engine management system the analyser will indicate that the MIL is on (*MIL:ON*), and the number of stored DTCs (Diagnostic Trouble Code) is given (**Figure 9e**) .There is now a choice between displaying the *trouble codes* or *freeze frame* data. For trouble codes the code number is displayed along with (in most cases) a detailed description of the fault (see **Figure 10**).

When the trouble codes are displayed, pressing key A brings up an option to clear the codes from the vehicle's memory.

More information about the failure can be gleaned by selecting Freeze Frame. When an error is detected by the engine management system the on board computer will take a snapshot or freeze frame of all sensor readings and store them in the vehicle's memory. A check of this data can provide a valuable insight into the cause of the failure. In selecting freeze frame trouble codes it is possible to select successive sensor values stored around the time that the failure occurred.

The example in **Figure 11** indicates a sensor reading when trouble was logged; trouble F000 a PID 0D (speed) of VSS = 33 km/h measured. Button A takes you through successive parameters while button B returns to the previous menu.

The downloadable user's manual contains overviews of all the menu options, selections and display messages. When you want to get more familiar with its operation, try the online simulator mentioned earlier, or better still put your order in and build your own OBD-2 Analyser! An extra file containing soldering and assembly hints can also be downloaded from the *Elektor Electronics* website.

(070038-I)

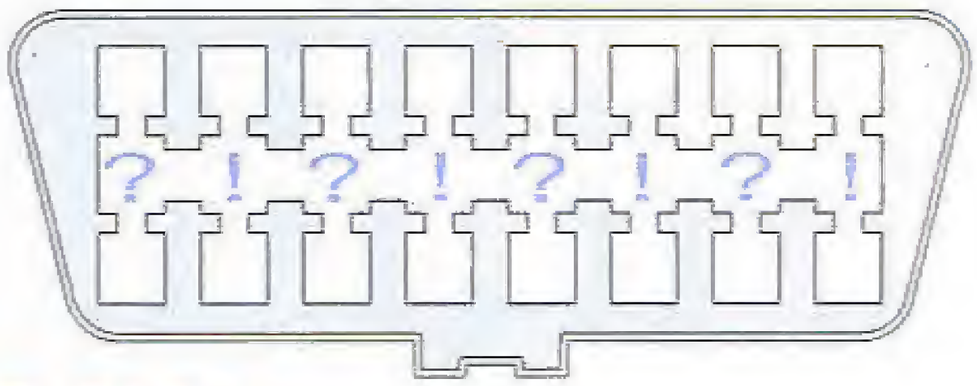
Literature

[1] Datasheet for the AGV4900-Controller: www.obd-diag.de

[2] Source of the AGV microcontroller: www.stange-distribution.de

[3] http://www.blafusel.de/misc/OBD-2_sconned.php

OBD



between Ecology, Marketplace and Big Brother

Dr. Thomas Scherer

OBD — the On Board Diagnostic for vehicles — was originally conceived as a system to reduce exhaust emissions and produce better air quality. Since its introduction, the ecological aspect of the diagnostic system has taken something of a back seat. These days the OBD is a key element in vehicle servicing for all garages. It has also become something of a marketing tool in the competition between dealership garages and independent garages. Information gleaned from the OBD connector can also be of interest to the manufacturer's sales department. When the next generation OBD-3 system is introduced, it may be able to pass vehicle information over a radio link to a roadside monitor as we drive by, and the politicians will convince us the system is in our best interests to improve air quality…

Back in 1930 the state of California had just six million inhabitants and an astonishing (at that time) two million cars. Ten years later almost every adult male Californian owned a car. In 1943 the city of Los Angeles suffered from choking smog (see video [1]). Exhaust gases were not thought to be the prime suspect at the time. In 1947 a national programme to monitor air quality across America was instigated. A milestone in environmental politics was reached in 1960 when research began into the effects on the atmosphere of exhaust gases. The link had been proven and in 1967 the Californian Air Resources Board (CARB) was setup with the remit to improve air quality. In 1971 CARB introduced a nitrogen oxide (NOx) emission limit on cars sold in the state and in 1976 reduced the lead content of petrol. In the same year Volvo became the first car manufacturer (**Figure 1**) to produce a vehicle with an electronically controlled three-way catalytic converter and lambda probe. This was not just an ecological and environmental breakthrough but also marked the beginning of electronic engine management in mass produced vehicles. By 1984 in California legislation was in place for all cars sold to be fitted with a system which monitored the exhaust gases and warned the driver when the limits had been exceeded. Already by 1982 work was in progress to standardise an on-board diagnostic system which could measure exhaust emissions. By 1988 all car makers endorsed this standard and OBD-1 was born.

Figure 1.
The daddy of them all: A 1977 Volvo 240 – The first volume car model to be fitted with an electronically controlled three-way catalytic converter.

Figure 2.
An OBD-Analyser. The Bosch KTS 115 is a handheld device similar to the stand-alone OBD analyser feature in this magazine.

California was the pioneer in exhaust emission regulation and here in Europe manufacturers were obliged to fit catalytic converters to cars sold in America but they were not available for the home market. Manufacturers were reluctant to fit them as standard because of the increased production costs. Effective lobbying by environmental groups across Europe has however succeeded in turning the situation around. Particle filters for diesel engines are also not yet obligatory, Peugeot have developed a highly stable and effective filter system that could have been fitted as standard to their vehicles since 2000 but so far it has only been offered as an extra. Diesel powered cars represent around 50 % of new car sales in some parts of the EU. The next generation of standards for cars ('Euro 5') have issued a directive which limits the emission of Particulate Matter (PM) to 5 mg of per kilometre which means that all new diesel engines manufactured from 2009 will need to be fitted with a particulate filter. The directive is less than six months old.

OBD-2 and EOBD

The original standard was relatively crude. It only monitored the oxygen sensor (the lambda probe), a possible emission recycler, fuel system and provided motor control based on the level of emissions. A flashing dashboard mounted lamp or MIL (**M**alfunction **I**ndicator **L**ight) was fitted and any detected errors were stored in a memory which could be examined via a serial interface by garage technicians during the next service.
Unfortunately the regulations were not specific enough so that each car maker came up with their own version of the interface. This caused havoc for many small independent garages who found it necessary to purchase third party OBD readers and adapters to allow them to carry out servicing on different makes of car. Even with these tools some manufacturers imposed restrictions so that not all the data could be read by a third party.
The weakness of the OBD-1 specification led to the OBD-2 standard which was released by CARB in 1994 and became mandatory for all vehicles sold in the state of California. Two years later it applied to all cars sold in America. EOBD is the European variant of OBD-2 and is essentially the same as the American model. This standardisation has a number of benefits to the manufactures by lowering production costs and also for independent garages by standardising test equipment. The wheels of EU bureaucracy grind exceedingly slowly so it was not until five years after the American regulations had been imposed that EOBD finally became mandatory for petrol engined cars sold in Europe in 2001 and then 2004 for diesel engined vehicles.
Vehicles fitted with the 16-pin EOBD diagnostic connector can not only pass sensor information as described in the standards document but also manufacturer specific information. OBD-2 and EOBD have far more sensor data, parameters and failure conditions than before. Many DTCs (**D**iagnostic **T**rouble **C**odes) and protocols are standardised. Worn out catalytic converters can also be detected along with other failure conditions brought about by general wear and tear.

Whose data is it anyway?

Apart from producing cleaner exhaust gases other aspects of the diagnostic system have become apparent. The car makers are installing ever more complex systems which can store far more information than the standard OBD-2 interface requirements. Smaller independent workshops do not have the resources or access to special manufacturer-specific diagnostic tools to read all the information stored in the vehicles management system. Buyers are persuaded that only dealership garages can offer a full service. For this reason it is essential and indeed intended to maintain a certain degree of interface standardisation so that independent garages are freely able to use the diagnostic information stored on board. Without this many independent garages would no longer be able to carry out vehicle servicing let alone fault tracing or repairs.
The outcome would be that independent garages would eventually disappear and the customer would be left with little alternative but to use a dealership garage. Not a free market but a monopoly controlled by the car makers, without competition prices would inevitable rise. On the other side of the coin manufacturers are anxious that certain information for example about their engine control techniques [2] [3] should be protected from their competitors' prying eyes. They have invested heavily in vehicle development and the future of their company depends to some extent on how well they protect their investment. The line between protected manufacturer specific data and open data which can be used for vehicle servicing is not so easy to draw and goes beyond the current EOBD standard.
Does anyone ever ask what happens to all the information that is downloaded from their car when it goes in for

Few people question what car manufactures do with all the data they download from a car when it goes in for a service.

a service? It would seem to make sense as long as the information was made anonymous for the vehicle manufacturer to use it to identify any trends that may indicate a weakness in the design of a particular model or engine. Surely we would all benefit if cars were designed to be more reliable? What would you say as the owner of a standard Ford Focus if the Ford dealership started sending you sales brochures about the new sports Focus ST? you probably wouldn't give it a second thought but what if you have been specifically targeted by the sales department because the last time you took your car in for a service it was 'noticed' from the diagnostic data that you tend to be a little heavy footed in the accelerator department? Would this be a harmless use of the data? How about if you have a major mechanical failure just after the vehicles warranty expires and before you can even begin pleading your case to the garage manager, a mechanic connects to the EOBD and announces that the breakdown was not surprising considering the way you drive!
These examples are of course entirely hypothetical but not outside the realms of possibility, the technology is available and so is the data, the modern EOBD system is no longer just an air purifier but also a Vehicle Data Recorder...

What does OBD-3 have to offer?

As technology becomes more and more sophisticated the question of how we can protect our right to privacy becomes ever more difficult to answer. No sooner had OBD-2 been successfully adopted than work begun on its successor OBD-3. In the meantime technological progress has made it possible to incorporate much more powerful and complex systems which would not have been feasible ten years ago. The initial indications are that OBD-3 will not just be an improved OBD-2 with faster processors and more memory capacity. The whole concept is undergoing a radical rethink. It is anticipated that the systems will be implemented throughout the world so the final proposal will be the result of the input from many interested parties and committees, needless to say the whole procedure will not be swift.
Some of the suggestions that have been mooted sound a little implausible if not laughable and are probably the result of feasibility studies rather than a considered design approach. It has been suggested for example that the number of vehicle sensors will be increased to measure such mundane things as the vehicle doors so that the next time the car is serviced the mechanic will be able to inform you that "the drivers door has been opened 623 times in the last year and the passenger door only 346 times, the hinges on the drivers door will need to be greased during the service, do you want us to do the passenger door as well?"
Much less bizarre is the suggestion (which many car manufacturers are currently working on) that the on-board OBD connector will be replaced by a radio link. In much the dame way as the RFID system is designed, each vehicle would have its own unique identity. One mode of operation would be used principally during servicing where large amounts of stored parameters would be analysed by the car mechanic to optimise the car's performance and change settings. Another mode could transfer a limited amount of information in a very short burst. When, for example the car is driven past a roadside monitoring system. This possibility of monitoring individual vehicles in a continuous traffic flow suggests a number of interesting applications; it would be possible to log each vehicles chassis number along with its instantaneous exhaust emission parameter and feed the information into a central computer where it can be evaluated. The owner of any vehicle over the emission limit may then be issued with a fine or advised to get the vehicle serviced in the next few days. Looking at the system in a slighily more sinister light we would now have the infrastructure in place and the information available to be able to track the movement of every vehicle... Big Brother would be proud of us.
The impact of 9/11 in 2001 has made the world a less secure place. Improved security is usually the reason given whenever steps are taken to increase the level of public surveillance but in this case it would be under the guise of 'efficient emission monitoring'. The probability that air quality will be significantly improved with a continuous level of surveillance compared to the current yearly MOT emission test is quite low. The first rule of criminal investigations when searching for a motive is '*cui bono*' (who benefits?) and it may be applicable to the deployment of an expensive nationwide monitoring infrastructure which eventually may have a more profound impact on our civil liberty than just the innocent ecological aim of monitoring exhaust emissions.

(070242-I)

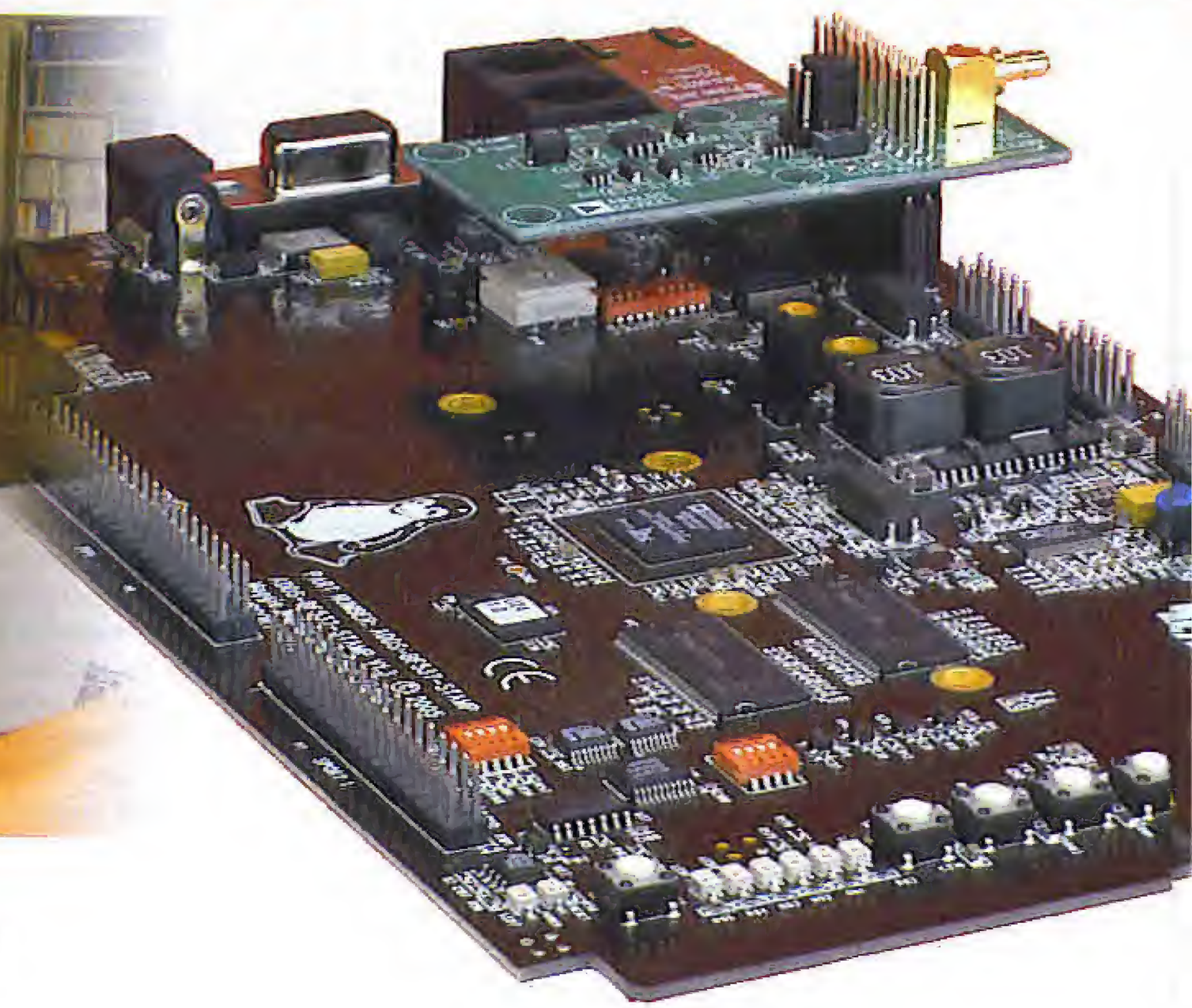
[1] www.arb.ca.gov/videos/clskies.htm

[2] Chip Tuning, Elektor Electronics July/August 2005, p. 24 ff.

[3] Warp speed on demand, Elektor Electronics January 2007, p. 62 ff.

Figure 3.
Big Brother's little helpers: cameras on gantries over German autobahns being introduced to log vehicle movements. Similar systems are being trialled in the UK. photo: Stefan Kühn (www.webkuehn.de).

Linux Oscillos



Sascha Hoverath and David Tews

Linux is used more and more frequently for the control of various electronic devices such as mobile phones, routers and satellite receivers. These devices often use a special derivative of Linux, which is called μCLinux. This variation has a small footprint and can be used on many different types of microcontrollers. As an introduction to this variant of Linux we look at the development of an oscilloscope based on Linux. This scope can even perform measurements via the Internet!

With the arrival of µCLinux for the Blackfin series of DSPs/controllers, the development of Internet applications for this family has become much easier.
In addition to making a µCLinux version that is suitable for the Blackfin controllers, Analog Devices also have a development kit in their program, called the BF537-STAMP or Stampboard. A number of additional modules are available, including a fast A/D converter. We are going to make an oscilloscope with the combination of this development kit and the A/D extension module. The unusual part of this project is that it is entirely based on µCLinux!

Why Linux?

Using Linux in embedded devices is not so much a question of 'being trendy' but more a question of not reinventing the wheel over and over again.
By using an existing operating system it is possible to save much time and money during the development phase. Most of the required software parts are already available in Linux. For example, writing and testing your own TCP/IP stack will require a lot of your time. But this is already available in Linux as standard.
Furthermore, drivers are available for all kinds of hardware and have already been extensively tested by may users.
In addition to that, Linux obviously also has the advantages of a multitasking system: the possibility of running multiple programs (apparently) simultaneously.
By choosing an operating system such as µCLinux, the designer can focus on those aspects that make his product different from those of the competition.

scope Development with µCLinux

Stamp-kit

The electronic heart of this project is the STAMP-kit. The processor power is delivered by a Blackfin537 controller, with a clock frequency of no less than 500 MHz.
The core of this chip has a strong resemblance to a DSP, because of the powerful instructions to generate loops plus the 2 MAC-units which can both multiply simultaneously and add the result to the previous instruction.
The internal data paths have also been designed in such a way that the controller can effortlessly process large data streams.
All this is provided with copious amounts of memory, namely 64 MB of RAM and 4 MB of flash memory. This is sufficient to accommodate a complete, functional Linux system including applications and together with a suitable bootloader.
Communicating with this board can be done via both a serial interface as well as an Ethernet interface.
All the important signals lines from the controller are available via headers. This offers the possibility of extending the board with all sorts of additional hardware.
In our case we use a fast A/D converter, which is available as a ready-made extension kit.

Software

The development kit, as standard, is delivered with a bootloader (U-Boot), a µCLinux-kernel and BusyBox pre-installed in its flash memory. U-Boot will be the first to run as soon as the hardware is powered up. This in turn will load Linux into memory and run it. You can follow the entire boot process via the serial port with a terminal emulator program, such as Hyperterminal, for example. The configuration of the serial port is quite standard: 57600 baud, 8 bits, no parity and 1 stop bit.
Once all this is done you have a working Linux system. The usual commands such as ls, cp, cat, etc. can be sent via the same serial port to carry out Linux tasks.
One thing is still missing: an application. This we will have to write ourselves. But before we get to that we have to install the development environment first.

Development environment

In our case the required development environment comprises 3 parts: µCLinux, the toolchain and the

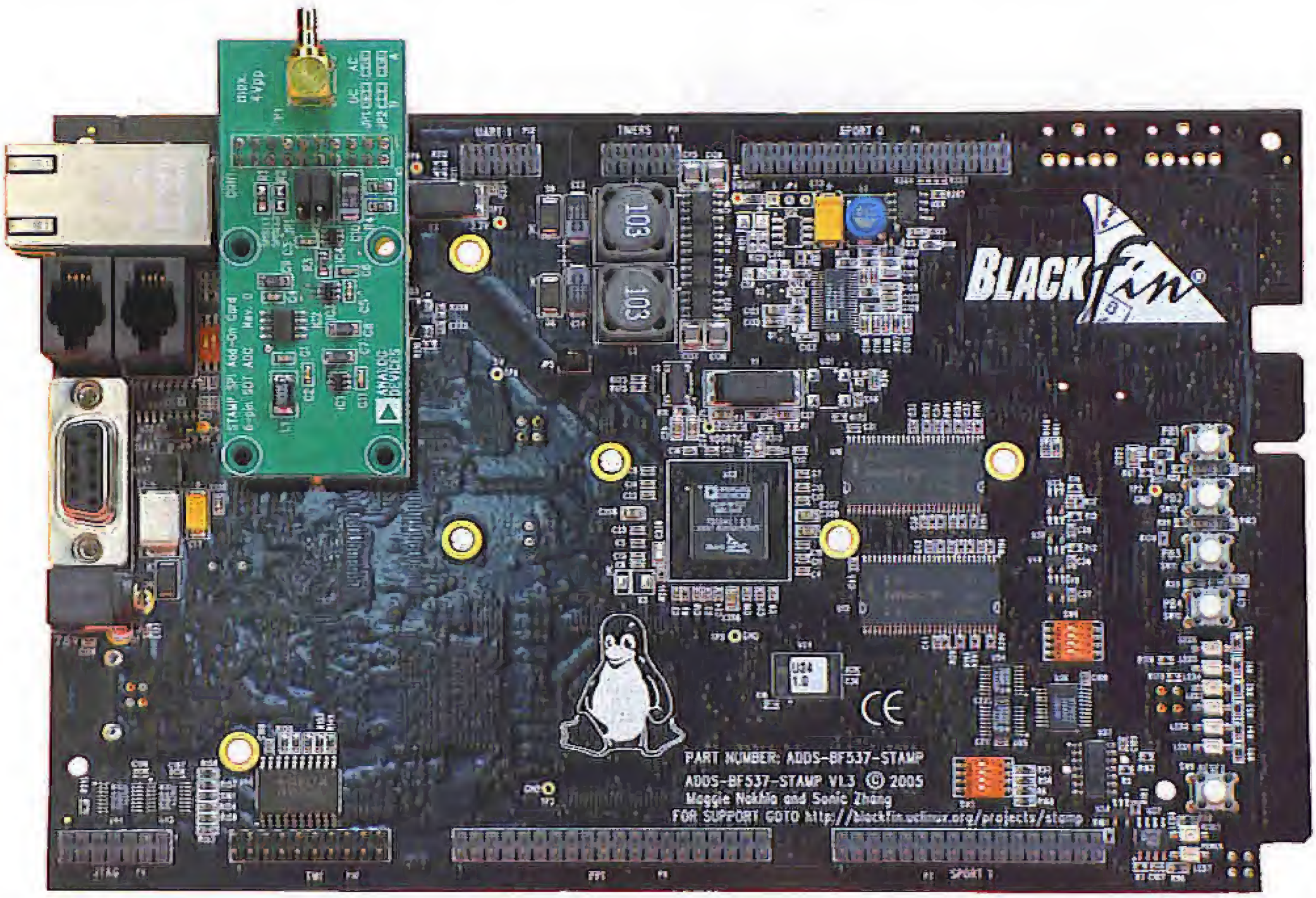


Figure 1.
Stamp Kit: the development-board including the A/D-extension.

bootloader U-Boot.
µCLinux contains the complete source code for the µCLinux kernel with BusyBox. To be able to compile the kernel, a cross-compiler and accompanying tools are required, the so-called 'toolchain'. This contains the gcc-compiler for Blackfin processors as well as a linker/assembler. In addition there are a number of utilities to convert between various formats, etc.
Finally we need U-Boot, because of a helper-program 'mkimage'. We need this program to convert our kernel into a format that can be read from flash memory by the bootloader U-Boot.
You can find the development environment that we used in the download that goes with this article. Note that this toolchain only works on Linux. If you really want to continue to work on Windows then you can use the program coLinux to allow you to develop Linux software. Unfortunately we cannot give you any details about how that works since we only worked on Linux while developing this project.
You can find instructions on the Internet how to install this development environment. We wrote a script for this purpose, to simplify things for you. The script installs all three components automatically.
This script is named 'installbf' and can be found in the folder '\blackfin\environment' in the zip-file that you can download from the Elektor Electronics website (EPS 060241-11). Use the command '`./installbf /`' to install everything from the root of the file system.

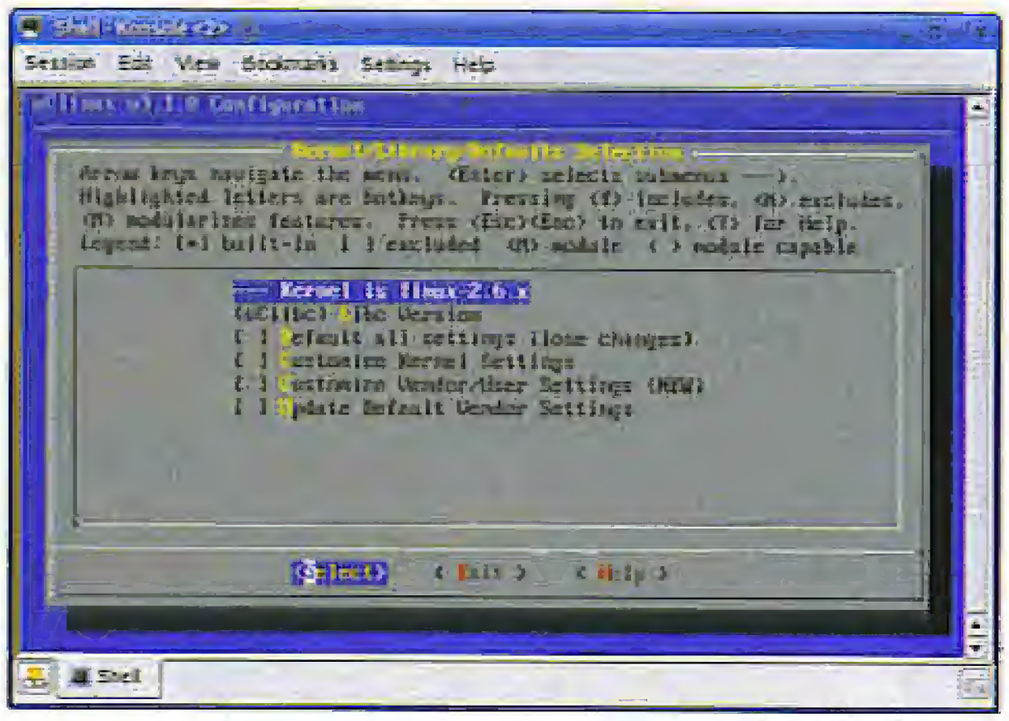


Figure 2. *Configuration of the kernel.*

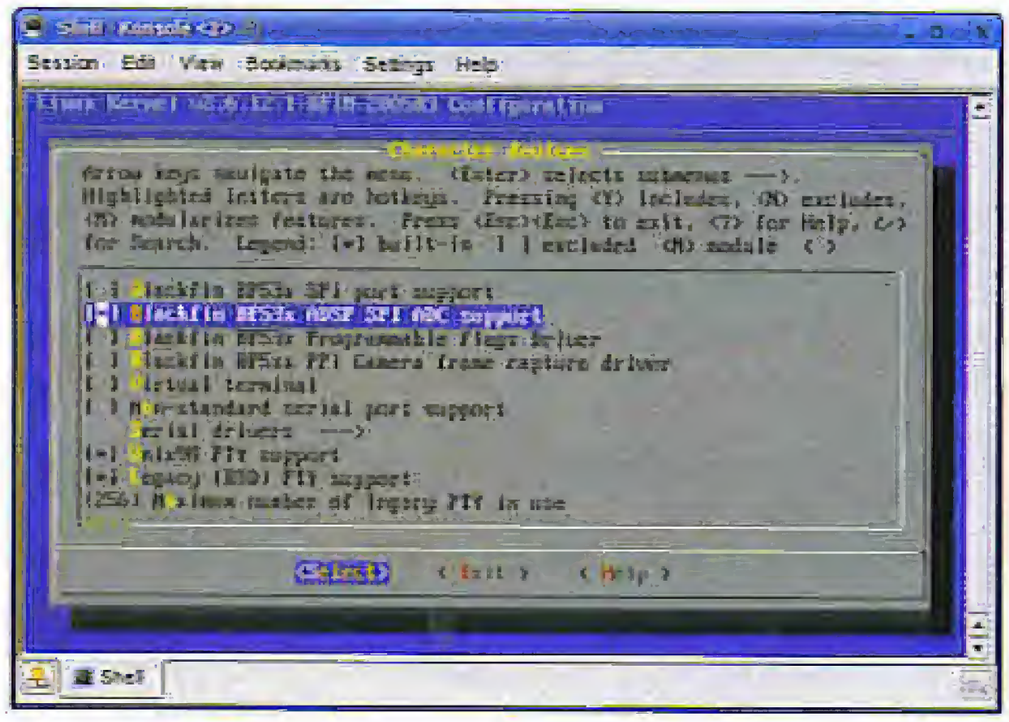


Figure 3. *Adding the A/D-driver to the kernel.*

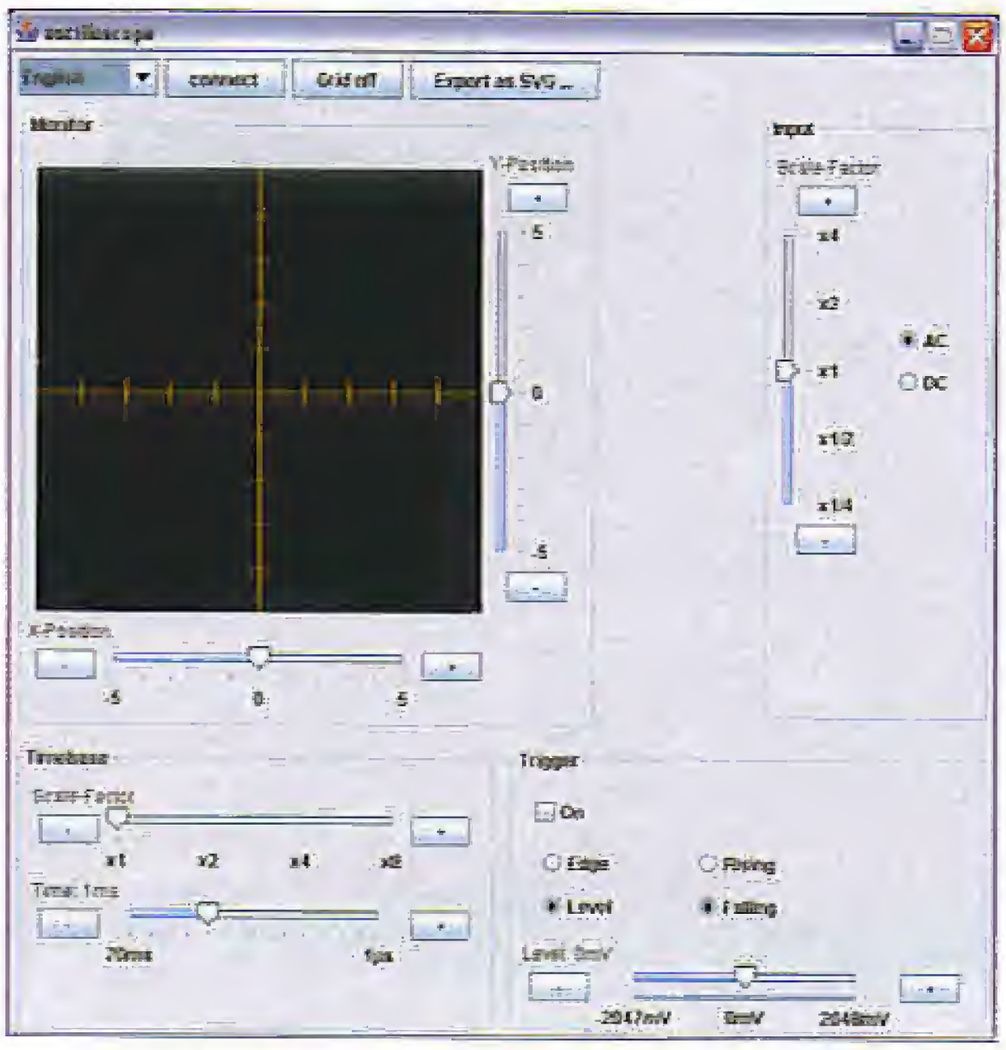


Figure 4. *Screen dump of the oscilloscope software.*

Configuration & testing of the installation

Before we can continue we first have to configure the toolchain. To do this we carry out the following commands in the folder 'uClinux-dist':

```
>make clean
>make config
>make
```

After executing the second command you will be surprised by a program that offers you the option of configuring the kernel and such.
First choose the option 'Vendor/Product' and select 'Analog Devices Products' in the next window. Now select the option 'BF537-STAMP'. After that leave the configuration window.

The program will now ask if you would like to save the new kernel configuration. Answer this with 'YES'.
The last command compiles the entire Linux kernel, including the accompanying applications. Beware! This can take quite a while when running it for the first time. So feel free to make a pot of coffee or go wash the car!
The result of all this effort is the file 'linux' that you can find in the folder 'uClinux-dist/images'.
Using, for example, a TFTP-program you can send this freshly-baked Linux version to the hardware and verify that everything works as it should.
If everything has gone well, you can now watch, with the aid of a terminal emulator, as this Linux software starts up.
We have now arrived at the point where we will write our own application and add it to our image.

Adding our own application

Our application is a server which sends measurement values from the A/D-converter via the network to a client. This application (which is called oszi) we therefore have to add to our source code.
To do this we add a folder named oszi in the folder '/uClinux-dist/user/'. All the source code for our software has to be stored in this folder.
We will need the customary Makefile, which contains the

instructions for compiling our software. In addition we have to change 3 more files so that the tool chain will compile our software as well.
In the folder '/uClinux-dist/user/' we can find a Makefile. We have to change this so that this makefile knows that our software exists. We only need to add the following line:

```
dir_$(CONFIG_USER_OSZI_ISZID) += oszi
```

That was easy, wasn't it?
The next two changes are required so that we can select the compilation of our software via 'make config'. These files are in the folder '/uClinux-dist/config'
The first file that we will deal with is 'Configure.help'. We add the following two lines to the end of that file:

```
CONFIG_USER_OSZI_OSZID
  Oscilloscope-Server
```

The last change we make to the file 'config.in'.
In the section 'Network Applications' we add the following line:

```
bool 'oszi'CONFIG_USER_OSZI_OSZID
```

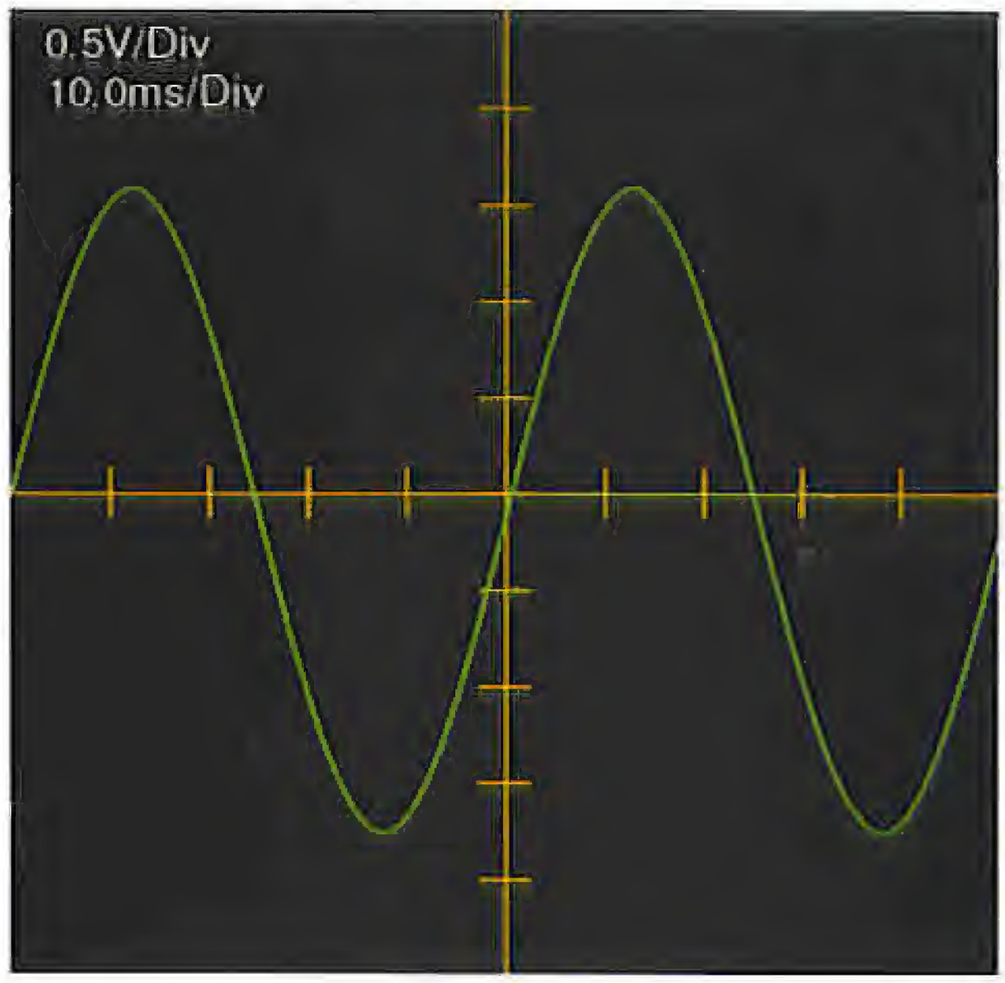
After all these changes we can configure the kernel via the now familiar 'make config'.
We are now going the change the kernel a little. To do this we select 'Kernel/Library/Defaults'.
On the screen that follows we indicate that we want to change both the Kernel settings as well as the User-settings.

Under the heading Character Devices we select the driver for ADC support. This driver enables the use of the A/D-converter from within Linux, which is what we need for our application.
Once we leave this window a new window appears where we can select which additional applications we want to compile as well.
Under the option 'Network Applications' we find that our own application. 'oszi' is now nicely listed with the other software. We select this option, obviously.
After we have saved this new configuration we can use the command 'make' to compile a new Linux kernel. This is sent to the hardware, just like last time, and we can now test the software.

Client software

We wrote a Java application for the client software. The advantage of this is that it is independent of the operating system. This software has been tested on both Linux as well as Windows XP. It should also work without any problems on, for example, MAC-OS.
The IP-addresses that have been used are fixed in the source code of the Linux software to 192.168.1.15 for the hardware. The client (PC for example) needs to have the following IP-address: 192.168.1.2. These can be easily changed if need be in the source code (of the Blackfin, obviously!).
We assume that at this point you have started the new kernel on the Blackfin board. By clicking the 'oszi.jar' file on the PC the client software is started.

Via the terminal we can instruct Linux to start the oscilloscope application with the commnd '/usr/oszid'.

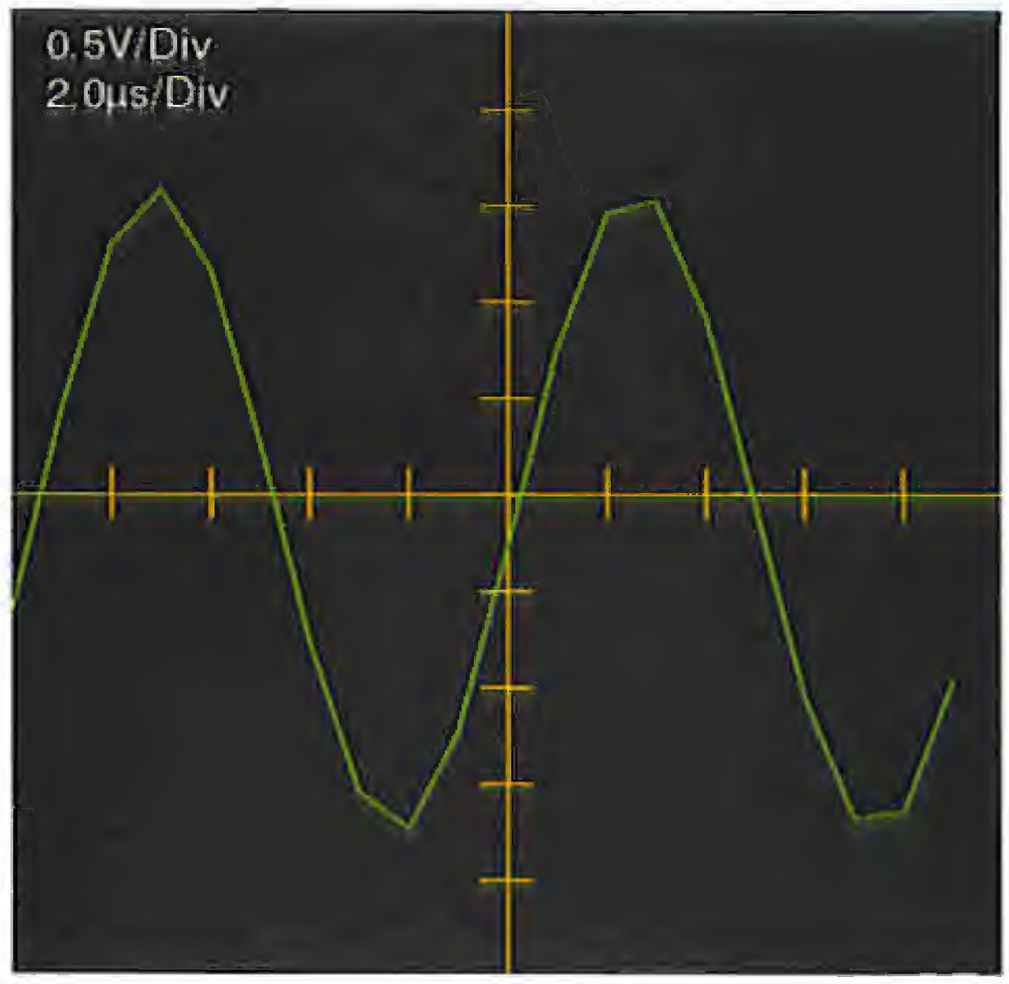


With a mouse click on the button 'connect' a network connection is established with the hardware. The measured values now appear on the screen in the shape of a graph, just as with a normal oscilloscope.
The maximum usable sampling frequency of this scope is about 200 kHz.

Server-software

A complete description of the server-software is unfortunately outside the scope of this article. The source code for this software contains comments, so it is not too difficult to figure out how it works.
What we don't want to withhold however, is how you can change the IP address of the server and the address at which our application expects to find the client PC.
In the file 'oszid.h' there is a line for the IP-address of the client PC:

```
#define IP_ADDR "192.168.1.2"
```



It is obvious that you can change this line to suit your needs.
If we add the following line to the end, we can ensure that the oscilloscope software will start automatically when the system is booted:

```
oszid &
```

To change the IP-address of the Linux-oscilloscope, we have to do the following:
Open the file 'rc' in the folder 'uClinux-dist/vendors/AnalogDevices/BF537-STAMP'.
In this file you will find a line with the command 'ifconfig'. Change this line as follows to, for example, obtain an IP-address of 192.168.1.3:

```
>ifconfig eth0 192.168.1.3 up
```

After these changes it is necessary to compile the kernel again (make, remember?).

Release

Once we are happy with our software it would be very convenient to store this in flash memory. In this way we also make sure that the software starts automatically when the hardware is powered up.
First, we have to make a so-called 'image' for U-Boot. Such an image contains all our software, which has to be compressed first. In addition this image contains a header that contains information as to the location of the image in memory.

This whole process is done via a script with the name 'mk_uImage'. You can find this script in the main folder of our download.
The final result 'uImage' is in the folder '/uClinux-dist/images'.
Start the hardware again and press the space bar in the terminal window. The bootloader is now in the so-called 'command mode'.
Give the following commands:

```
>tftp 0x1000000 uImage
>erase 0x20100000 0x203FFFFF
>cp.b 0x1000000 0x20100000 $(filesize)
>bootm 0x20100000
```

The first command sends the file uImage from the PC to the RAM on the hardware.
The next command erases the last 3 MB of the flash memory. This is then programmed with the file that you just loaded.
The last command ensures that U-Boot unpacks this image into memory and runs it.

Final words

The development of software with the aid of µClinux is a fascinating affair. For starters, consider all the standard possibilities that this operating system has to offer. Hopefully this article has whetted your appetite to get started with µClinux yourself, with or without the hardware described here. Many have already gone before you!

(060044-I)

µCLinux and Busybox

The Linux operating system has become famous as a desktop or sever operating system. Over the years this operating system has been developed by countless users into a powerful entity, and will continue to be developed in the future.

The current Linux is actually much too big for embedded systems. In addition, standard Linux requires a so-called memory manager. This is a piece of hardware inside the processor, which can ensure that each application has its own chunk of memory without accidentally overwriting the memory of another application.

The controller in a standard embedded system does not typically contain such hardware.

The desire to be able to use Linux on a controller with a limited amount of memory and without a memory management unit has led to the development of µCLinux. This is a version if Linux that can operate without a memory manager.

Linux is built in a very modular fashion, so that those parts of the kernel that are not used can simply be omitted. By also stripping the accompanying library from unnecessary frills the whole thing can be quite small.

A piece of hardware with only an operating system is of course completely useless. That is why standard Linux contains a whole gamut of smaller tools, such as for example programs to copy files, make folders or navigate the file system. All these separate commands are normally small applications. A large collection of these tools results in a large memory requirement for storing all these standard commands (applications).

BusyBox was developed to save even more memory. This software is able to carry out all the standard commands on a Linux system. A single program occupies much less space than a large number of individual programs. The BusyBox user does not notice at all that these commands are now processed by BusyBox instead of individual programs.

Booting with a submarine: 'Das U-Boot'

After a reset, a controller will always execute code that can be found at a fixed address location. In our case the Blackfin will try to run the code that is stored at the start of the flash memory.

At this location is normally the program 'Das U-Boot', which is often abbreviated to 'U-Boot'. This program is a so-called bootloader and is comparable to the BIOS of a normal PC. Its main task is to start the Linux kernel. To do this, the Linux kernel has to be unpacked first, considering that this is normally stored in flash memory in a compressed form.

Once unpacked, the Linux kernel is in RAM and the controller is instructed to execute this code.

In addition to this main task, U-Boot has a large number of additional functions. These are all related to the loading of programs plus the erasing and programming of the flash memory.

U-Boot can, if required, load a program over the network with TFTP (Trivial-FTP) or even NFS, and execute it. This is obviously also possible via the serial port, but it will clearly be much slower than via the network.

This functionality is very handy during the testing stages of the development phase of the software. This method of testing avoids the need to repeatedly erase and reprogram the flash memory.

When first started, U-Boot will wait a predetermined amount of time. If a space character has been received through the serial port within this time, it will change over to command-mode. If not, it will carry out its assigned task (start Linux).

How U-Boot does this is communicated with environment variables. These variables are also stored in flash.

In command mode you can send various commands to U-Boot. With the command 'print' U-Boot will show all the current environment variables. The most important variable is 'bootcmd'. This one indicates what U-Boot has to do when a space character is received during the initial wait loop.

These variables look like this:

```
bootdelay = 5
bootcmd=bootm 0x20100000
```

In the above example, U-Boot will wait for up to 5 seconds for a space character from the serial port. If this time elapses and no space has been received then U-Boot will execute the command 'bootm 0x20100000'. This means that U-Boot expects an image at address 0x20100000, unpacks this into memory, verifies its integrity and finally instructs the controller to run the program it loaded.

TFTP

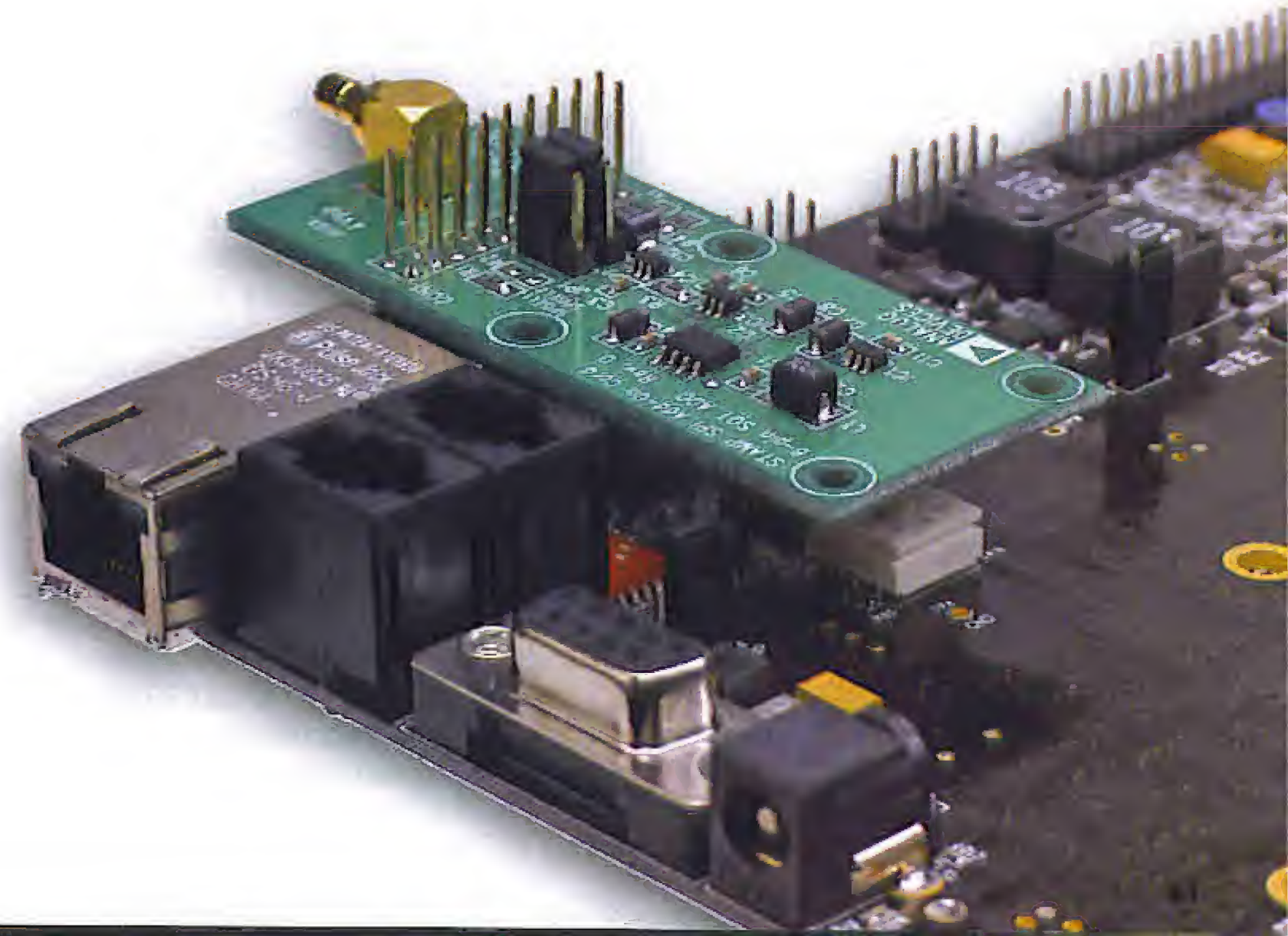
During development it is likely that a new version of software needs to be loaded frequently. To ensure that U-Boot loads the new software automatically from your PC using the TFTP-protocol, it is best if you change the 'bootcmd' into

```
Bootcmd = tftp 0x1000000 li-
   nux; bootelf 0x1000000
```

Het commando hiervoor in U-Boot is als volgt :

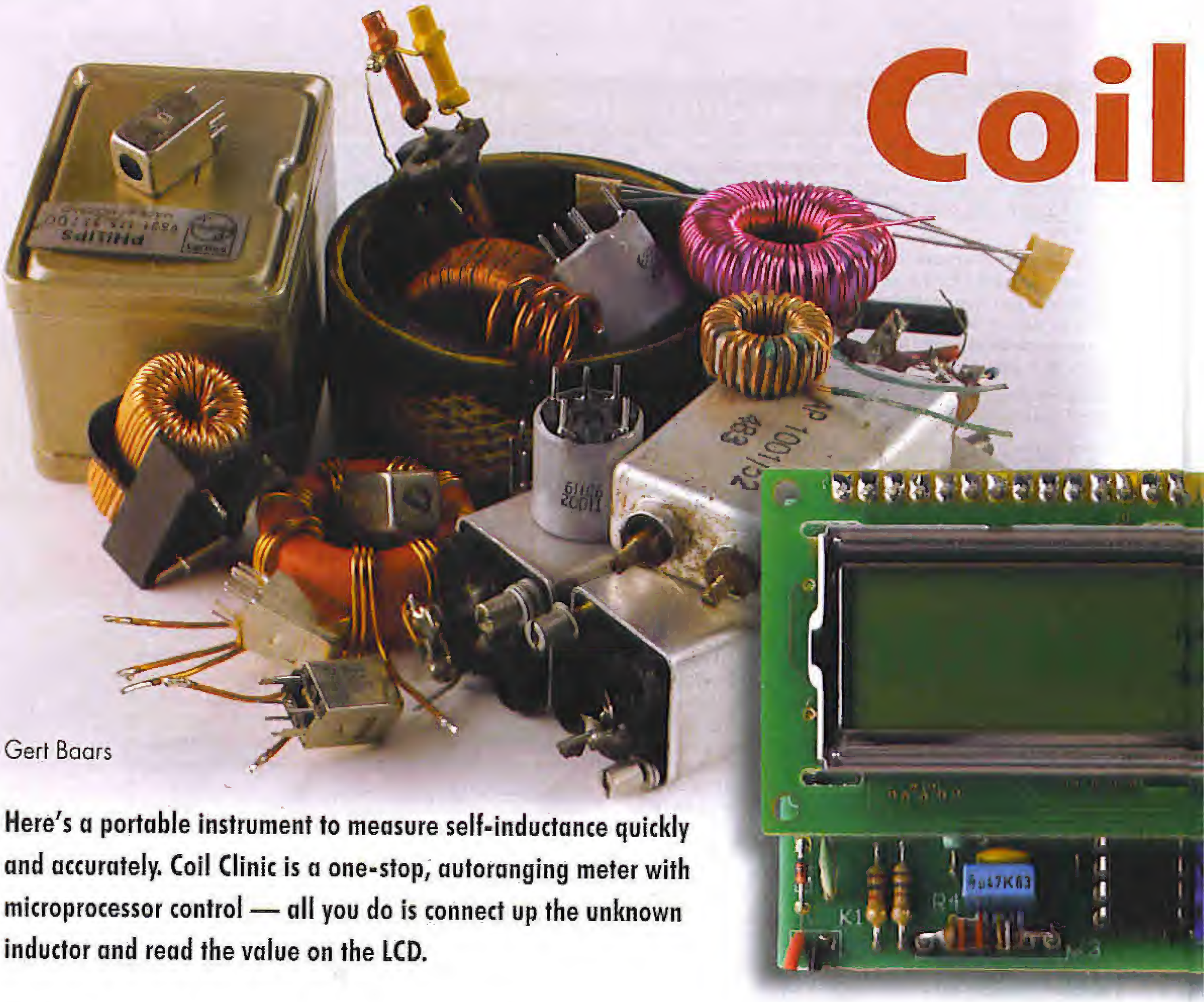
```
set bootcmd = tftp 0x1000000
   linux;bootelf 0x1000000
saveenv
```

The last command ensures that the environment variables are saved in flash, so that these variables are not lost when the power supply is disconnected!



Coil

Gert Baars



Here's a portable instrument to measure self-inductance quickly and accurately. Coil Clinic is a one-stop, autoranging meter with microprocessor control — all you do is connect up the unknown inductor and read the value on the LCD.

The inductor with its property 'inductance' (symbol: *L*) is one of three low-down passive components around which all electronics has evolved, the other two being the resistor (symbol: *R* for resistance) and the capacitor (symbol: *C* for capacitance). Of the three, the inductor is the one that seems to divide whole communities in two: you either love it or hate it. The latter opinion is held by many of the younger generation who get frustrated by inductances being present literally everywhere in circuits — but totally invisible! These 'stray inductances' you need to develop a keen eye for. No problem for the seasoned radio amateur but a source of confusion and headaches for newcomers cheerfully installing a 50-cm long wire to carry a high-impedance millivolt AF signal from one board end the other, and then wondering why Vatican Radio blesses their construction at nightfall, or (with less interesting stuff to listen to), mum's hairdryer!

Other skills most 'simulation-generation' enthusiasts have difficulty mastering in relation to inductors include guesstimates of the inductance (i.e., the inductor's self-inductance and from there, its operating frequency) and winding one's own coils. The latter job is fraught with pitfalls and hassles: knowing the core and wire properties, number of turns, finding a suitable core and understanding the difference between nano-, micro- and millihenries (nH, µH and mH respectively).

To add to all the misgivings, few, if any, digital multimeters support inductance measurement. And to cap it all, the fixed and adjustable inductor industry is mostly Asian and Japanese (Toko, Murata *et al.*) with a solid tradition of producing quirky type-designations and a lot of unbranded no-name aftermarket components.

In the end, most head bashing and objections against the humble inductor can be sussed out if help is available to 'find out the value of the thing'. And that's where Coil Clinic comes in.

Principle of the measurement

After some research, resonance-frequency measurement was found the best method available to make Coil Clinic work over the stated inductance range. Another method was abandoned but needs to be mentioned here for the sake of completeness.

Due to its self-inductance property, an inductor supplies a voltage that's proportional to the *variation* of the current it carries. Consequently, an inductor supplies a square wave when fed with a ramp (triangular) current. The amplitude of the square wave is proportional with the rate of rise of the current and likewise with the inductance we're hoping to measure. In prac-

Clinic

Coil Clinic quick specs

- Measures 100 nH to 99.9 mH in one range
- 2% resolution (approx.)
- Direct readout on LCD
- Battery powered
- Battery status indicator
- 35 mA current consumption
- ATMega48 microcontroller

A 100 nH to 100 mH single-range inductance meter with LCD readout

tice, an effect called 'ringing' (damped oscillations) spoils the accuracy of the proposed method, not forgetting the inductor's series resistance wreaking havoc at lower frequencies.

The resonance frequency f_r of an LC network is not too difficult to calculate from

$$f_r = 1 / (2 \pi \sqrt{L C})$$

Now, if C has a fixed, known value, the we can isolate L as

$$L = 1 / C (2 \pi f_r)^2$$

and deduce it from the resonance frequency measured by a suitable circuit such as a microcontroller.

To prevent any kind of range switching, an oscillator was developed capable of covering a wide frequency range using one and the same, fixed, capacitance C.

The output of the wide-range oscillator is then fed to the microcontroller set up to 'gate' its internal counter for 100 ms before being disabled again. The result in this case is the output frequency divided by 10. Using the above formula (in software!) the microcontroller converts frequency to inductance value and shows the latter on a display.

Practical circuit

The theory (almost) over we can have a look at the circuit diagram in **Figure 1**. Not much there, really.

Because the microcontroller runs at 'just' 20 MHz, the highest frequency that can be accepted from the oscillator is about 8 MHz. A normal Colpitts oscillator configuration cannot be used because the Q (quality factor) of the LC circuit will be low if small inductances are measured with a relatively small (fixed) C. After all, the internal gain of the oscillator has to be greater than unity (1) not just to overcome LC losses but also to afford the required high bandwidth of about 8 MHz without stalling or trouble starting.

The AD8099 fast opamp from Analog Devices has a high open-loop gain coupled with a high input impedance to minimise the load on the LC network. In this special configuration, oscillation occurs not chiefly because the LC network impedance maximizes at resonance (as the textbook will tell you), but rather because the phase shift is zero degrees at resonance. This interesting characteristic affords quite accurate measurements as will be seen later.

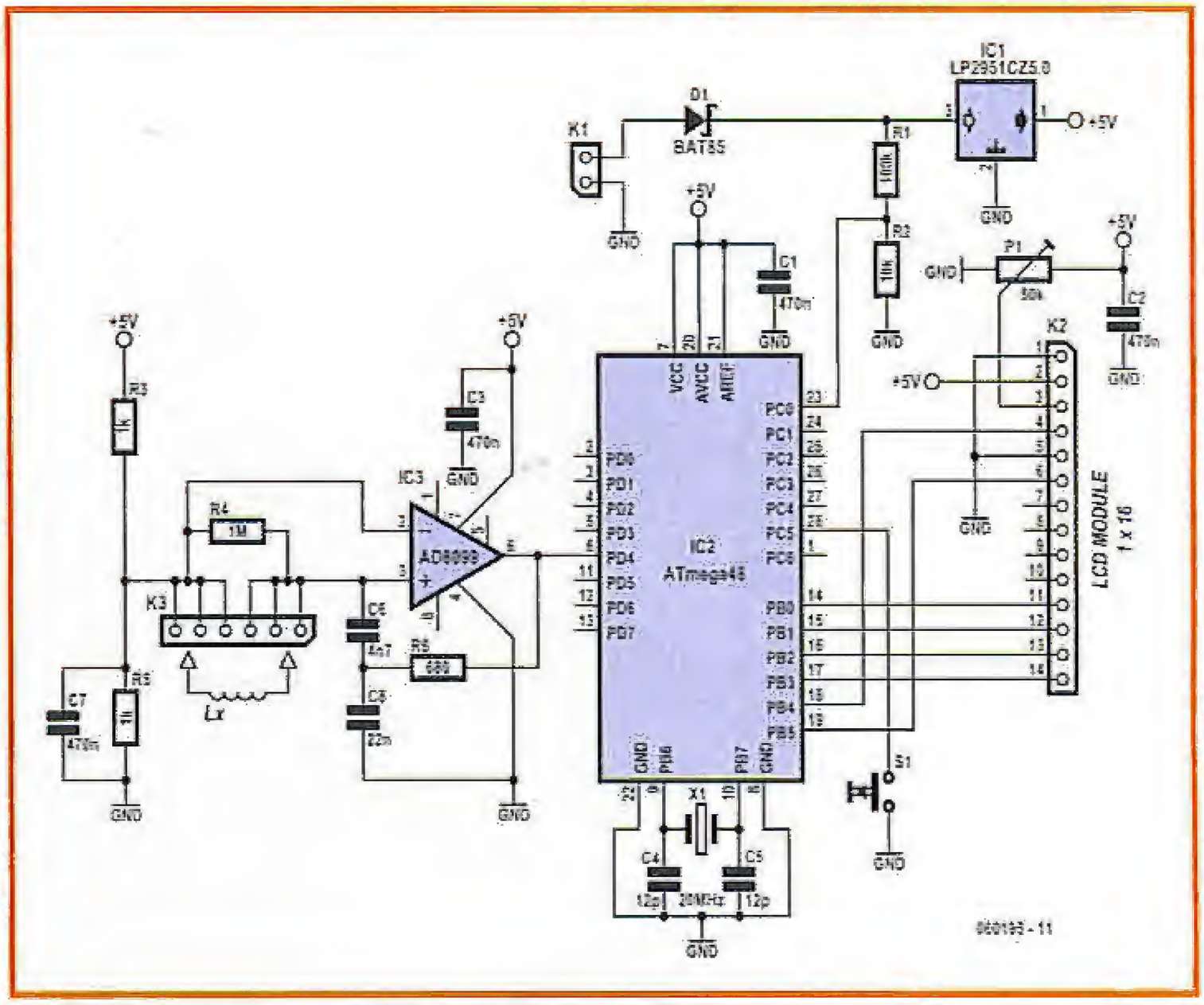


Figure 1. Hardware-wise, this is all there is to Coil Clinic — an ATMega driven inductance meter with direct LCD readout and no range switching. The crux of the circuit is the wideband oscillator around the AD8099 opamp.

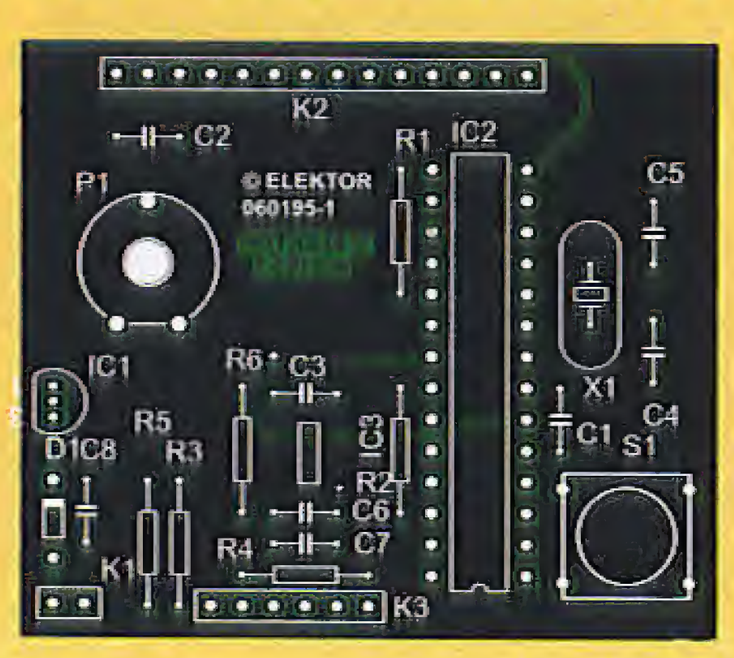


Figure 2. Double-sided PCB for the inductance meter.

COMPONENTS LIST

Resistors
R1 = 100kΩ
R2 = 10kΩ
R3,R5 = 1kΩ
R4 = 1MΩ
R6 = 680Ω
P1 = 50kΩ preset

Capacitors
C1,C2,C3,C7 = 470nF
C4,C5 = 12pF
C6 = 4nF7
C8 = 22nF

Semiconductors
D1 = BAT85
IC1 = 78L05
IC2 = Atmega48-20PU (order code 060195-41)
IC3 = AD8099ARDZ

Miscellaneous
S1 = pushbutton, e.g. RA3FTL6 (Multimec)
X1 = 20MHz quartz crystal, low profile
Alphanumerical LCD module, 1x16 characters, HD44870 compatible (see text)
K2 = 14-way SIL pinheader
K3 = 6-way SIL receptacle strip (see text)
PCB, ref. 060195-1 from Elektor SHOP

Source and hex files for ATMega48, free download from www.elektor-electronics.co.uk

Finally, the circuit is powered by a low-drop low-power 5-volt regulator, which takes its input voltage from a 9-V PP3 battery. Preset P1 is the LCD contrast adjustment.

Software and the micro

The oscillator output is directly fed to the PD4 (counter) input of the ATMega48 microcontroller. This input is gated for 100 ms under software control, and the resultant ÷10 signal (i.e. $f_x/10$) is 'slow' enough for measuring, again in software. In fact, about 95% of the functionality of Coil Clinic is due to carefully designed firmware running in the ATMega chip.
Measurements and calculations were programmed in assembly language. The source code (.asm) and object code (.hex) files for the project are available free of charge from our website as archive file # **060195-11.zip** (June 2007). You may want to have the .asm listing available to be able to follow the discussion below.
Of two internal timers available in the ATMega48, one is used as a frequency counter and the other, to governs the 100-ms gate signal. Use is made of the counters' ability to generate internal interrupts on an overflow condition. The timer used as a counter has a width of just 8 bits. However, by incrementing a 16-bit register by 1 on each overflow, the effective width becomes 24 bits which is ample for our purposes.
The timer 'doing' the gate time is set up as an up-counter and features a prescaler. A fairly accurate gate timing is achieved by clever use of the prescaler and pre-load parameters.
Computing the *L* value from the measured frequency represents a heavy load to the micro. Sure, it can add, subtract and multiply, but you will look in vain for assembly code instructions to do divisions. Like it or not, at some point it is required to divide a 24-bit number by... another 24-bit number. A workaround was found in the use of the 'long division' method we learned at school many moons ago. Here, it is done at bit level! As the author discovered, writing a long division in assembler language is not accomplished during tea break, in fact it forced him to call in the help of the internal debugger in AVRStudio 4.0. The debugger was found to be an invaluable aid in tidying up the code, weeding out minor errors, oversights and the odd bungle, and generally tweaking the code.

Construction

Luc at Elektor labs has again succeeded in designing a PCB for the project that's so nice & clean we can safely print the copper track layout on our website and the component mounting plan in **Figure 2**. As you can see, the board is double-sided with plenty of copper pour at the solder side to act as a ground plane.
The 8-pin AD8099 is an SMD component which will require the most attention when wielding the soldering iron. After the 8099, it's all plain sailing as only through-hole parts are involved.
The ATMega48 micro is best fitted in a 28-pin narrow-DIP socket.... come again? ....which is made from two strips of SIL pin receptacles cut to 14-way length.
Although the LCD is operated in 4-bit mode, the PCB has a 14-way connector as we also need to cater for E (enable), RS (register select), contrast and the LCD supply voltage.
The LCD may be a general-purpose device with 1×16 characters, as long as it has the HD44780 controller (or equivalent). For the lab prototype we used an MC16011A-STR from Farnell, order code 1ZZ0423, which can be plugged directly onto K2. Make sure you know the connections of the LCD module you intend to use.
Figure 3 shows the last prototype of the meter. Preset P1 was improvised, but its

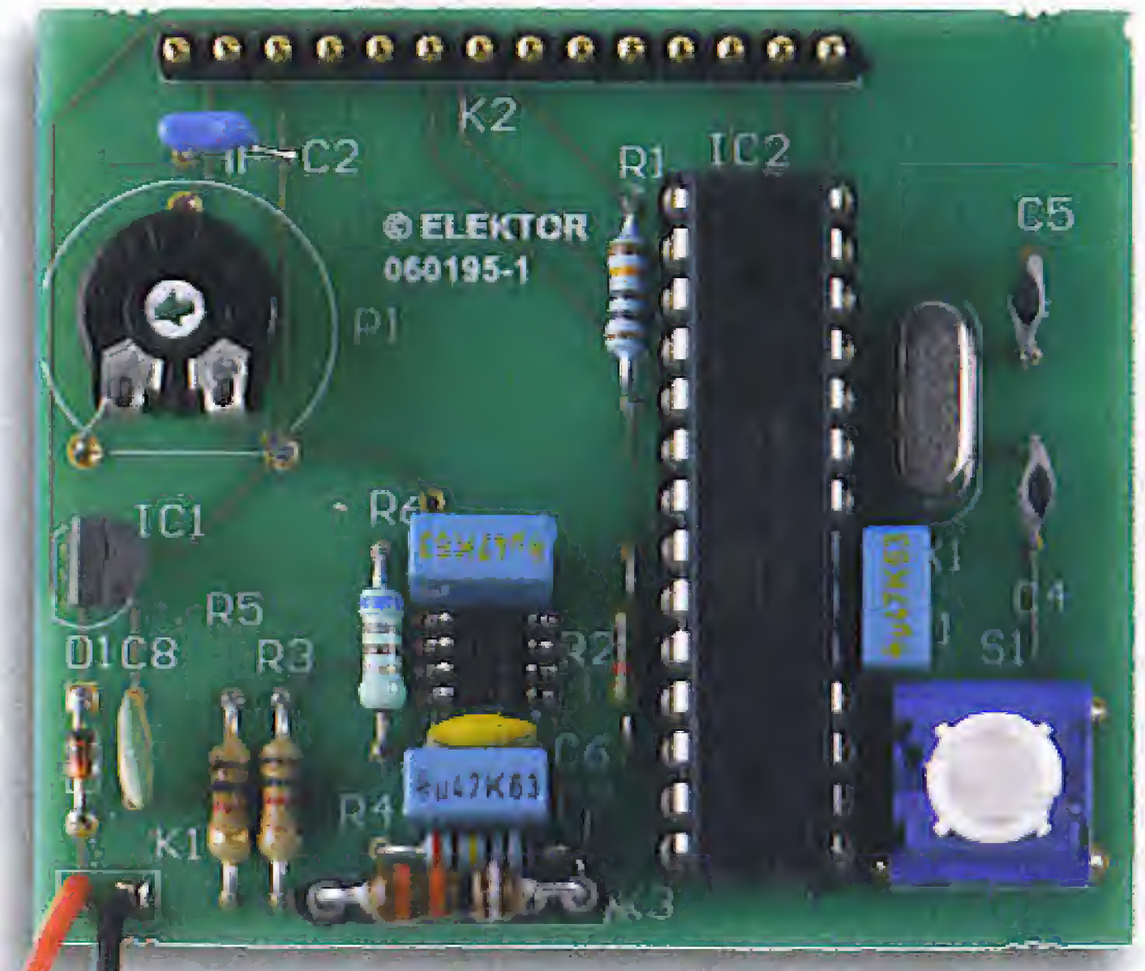


Figure 3. Prototype of the board.
The footprint for P1 has been corrected in the final PCB artwork.

footprint is correct on the final PCB layout. The unknown inductor is inserted into K3, a piece of SIL receptacle strip cut to 6-way length. Another piece may be stacked on top so you can easily replace it when it wears out or gets damaged. Two sets of three receptacles are in parallel to allow several lead pitches for these components. If you have to use wires between the board and 'L_x', keep them as short as possible. Do not touch the leads while measuring, on penalty of incurring a lot of stray inductance.
The finished board and LCD module should be easy to fit in a compact plastic or metal case with a battery compartment and an LCD window.

Calibration

Do not attempt to calibrate the instrument if it does not work yet. With the microcontroller up and running you will see 'OVER' on the LCD. Did you get the LCD contrast right with the preset? Good, continue. Short-circuit the L_x inputs and check that 'NO VALUE' appears.
The calibration calls for two reference inductors, one 22 µH and one 220 nH (yes that's 0.22 µH). The first is for the correction factor measurement, which is required to level out the tolerance on the ceramic caps in the oscillator. The 220 nH inductor, then, serves to compensate the length of the connecting tracks to L_x (and wires, if any).
From a batch of 5 to 10 220 nH inductors (E12-series miniature chokes), select the one that comes closest to the *average* value of the batch (measured with Coil Clinic). The same is done for the 22 µH inductor also needed for the calibration. If you find large deviations from 22 µH (i.e., below 16 µH or above 26 µH) then the 12 pF ceramic caps need to be reviewed. Best results are obtained if the uncalibrated meter achieves an accuracy of about 10% at this stage already.

Switch off the meter, depress S1, switch on again and release S1. You will see the message: 'Place L1=22.0 uH' on the LCD. Connect the calibration inductor and press S1 again. Disconnect L_1 and connect the 220 nH inductor (L_2). Press S1 again. With this inductor also checked and measured, Coil Clinic will display: 'Calibration OK'.
The correction factor and offsets so established are stored in the EEPROM in the ATMega chip and will be recalled and applied every time the instrument is switched on. Calibration is required only once, and afterwards the meter is ready for instant use.
The LCD will show an error message if L_1 or L_2 is not connected up, or if an out of the blue value is measured. Calibration data are then ignored until, during a proper calibration, values are available that do make sense.

Accuracy & resolution matters

A deviation of 0.1 µH equals only 0.45%, which is negligible considering the total error of up to 2% caused by number rounding. The 2% resolution in turn, is insignificant if you look at the tolerance stated for cheap off the shelf E12-series chokes, which is another way of saying that Coil Clinic can be pretty accurate, but it all depends on the accuracy of the calibration process.

Practical use

KISS applies here: connect up the mystery inductor and read the value on the display! No range switching or estimating required.

Now try this at home:

- What happens if you spread the turns of an air–cored inductor?
- What if you insert a core (ferromagnetic or metal)?
- What if long connecting wires are used?
- Wind a coil loosely on a ferrite core, measure L_1, and then remove the core. Measure L_2. Hey presto the 'μ_r' parameter of the core material equals L_1/L_2.
- Slide a small ferrite bead up a length of wire and see what happens.
- Measure the L value of a window or rhombic antenna and use it to calculate C required to tune for resonance in a specific frequency band.
- Find out the crucial A_L spec of an unmarked ferrite ring core — wind 10 (n) or so turns evenly on the core. Measure L, from which: $A_L = L / n^2$.

A special case exists with inductors larger than 100 mH ('OVER' readout). These can be measured indirectly with the help of a reference inductor, as follows. First, measure the known inductor, note its value and call it L_1. Now connect the unknown specimen in parallel with L_1 and repeat the measurement, noting the value as L_2. The value of the large inductor, L_x, is calculated from

$L_x = 1 / (1/L_2 - 1/L_1)$
For example, with L_1 = 47.5 mH and L_2 = 45.0 mH on the display we get

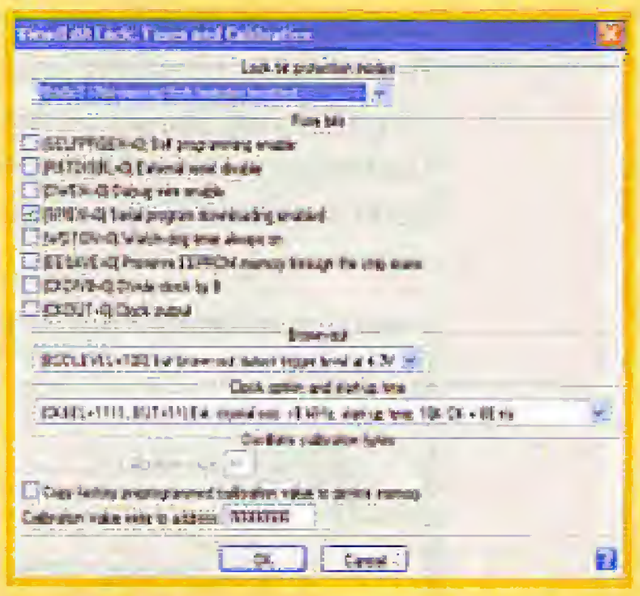
$L_x = 1 / (1/45 - 1/47.5) = 855$ mH.

In principle, inductors smaller than 100 nH can be measured, too — simply connect a known inductor in series. However, the inductance of the connecting wires may cause problems; just remember that a wire piece with a length of just 1 cm easily represents 10 nH. 'NO VALUE' is displayed if the meter 'sees' a short-circuit or an inductance only UHF and SHF technicians care about.

The message 'LOW BATTERY' will flash every 10 seconds or so if the battery approaches the 'flat' state. The voltage measurement is performed by an ADC on board the ATMega48 chip. Although measurements are still possible for a while, replace the PP3 as soon as possible. Fortunately, inductance measurements normally take little time to perform, so the battery should last for years.

(060192-I)

ATMega48 fuse settings



This is a tricky one mainly because of the clock setting. If you get it wrong, the software will run so slow characters can be seen typed one by one on the display like an old fashioned RTTY. Screendump shows the settings on the Elnec SmartProg2 programmer in the Elektor lab.

```
BOOTSZ=11
BODLEVEL=1
CKSEL=1111
SUT=11
```

Flowcourse: Alarm

Handling stimuli

Jean-Paul Brodier

The first two articles in this series show how the microcontroller is capable of 'playing all alone' – the only interaction with the outside world is the emission of light by the LEDs. To do something more useful, the microcontroller needs to react to conditions or events in its environment, which robotics engineers call stimuli (singular: a stimulus).

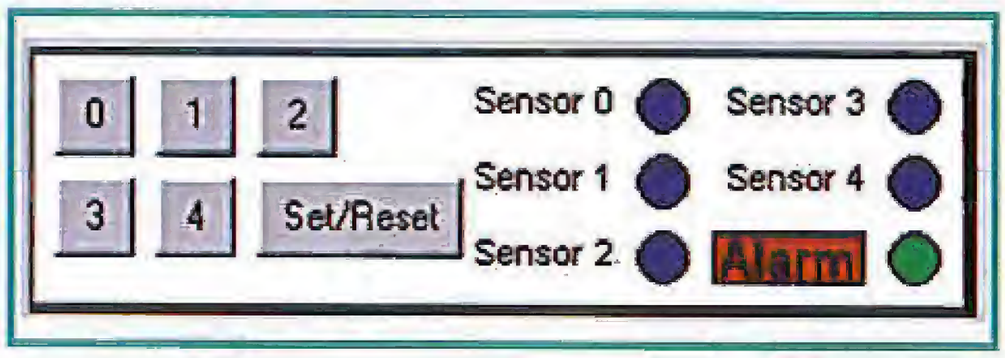


Figure 1. Keypad and indicators for the alarm system. (Source: Matrix Multimedia)

The second example given in *Flowcourse* (on CD-ROM) describes an intruder alarm that lights an LED in response to sensor activity. It is configured and set by a series of buttons. The signals produced by the sensors and the buttons are the *stimuli* that are will determine the behaviour of the microcontroller; we shall be seeing how the program takes these signals into account.

The installation (see panel in **Figure 1**) comprises six intrusion sensors and six buttons, one of which is used for set/reset. On the output side, there are just two LEDs. One indicates that the system is armed, the other, that an intrusion has taken place. In a real application, when the LED lights, a relay is also energized to power a siren, lighting, or trigger telephone reporting of the alarm.

The set/reset button makes it possible to arm or disable the alarm system depending on the moment in the day.

The sensors are normally-open contacts. When they are operated, they take the corresponding microcontroller input to logic high.

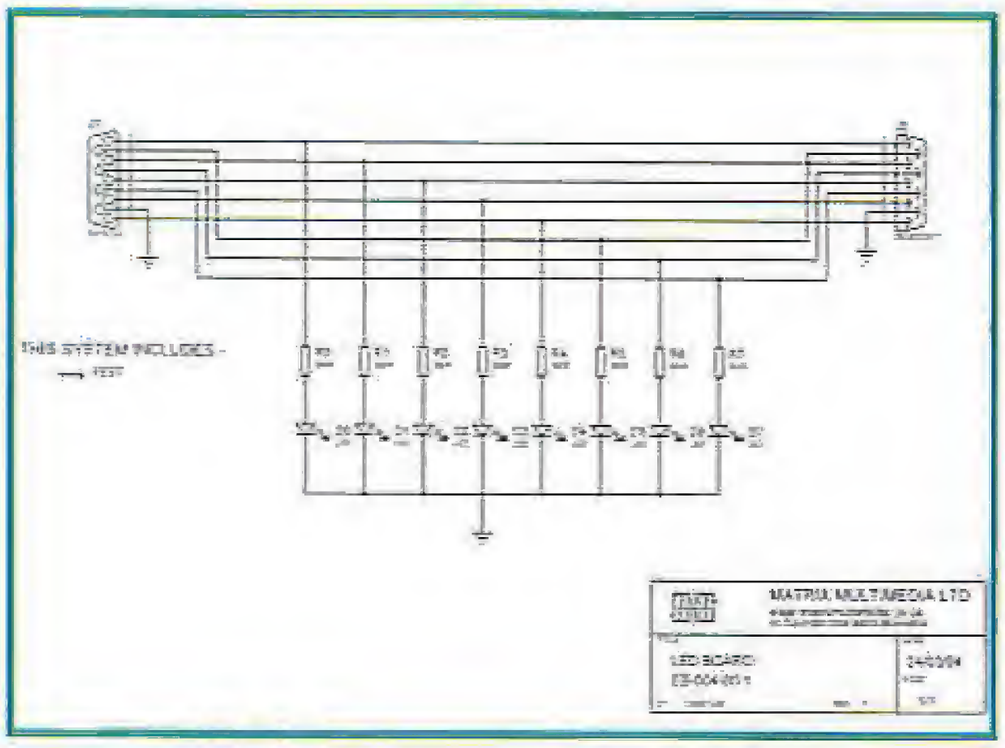


Figure 2. The 8-LED board is self-contained, the LED anodes are connected via 560 Ω resistors to the port outputs, the cathodes to earth. (Source: Matrix Multimedia)

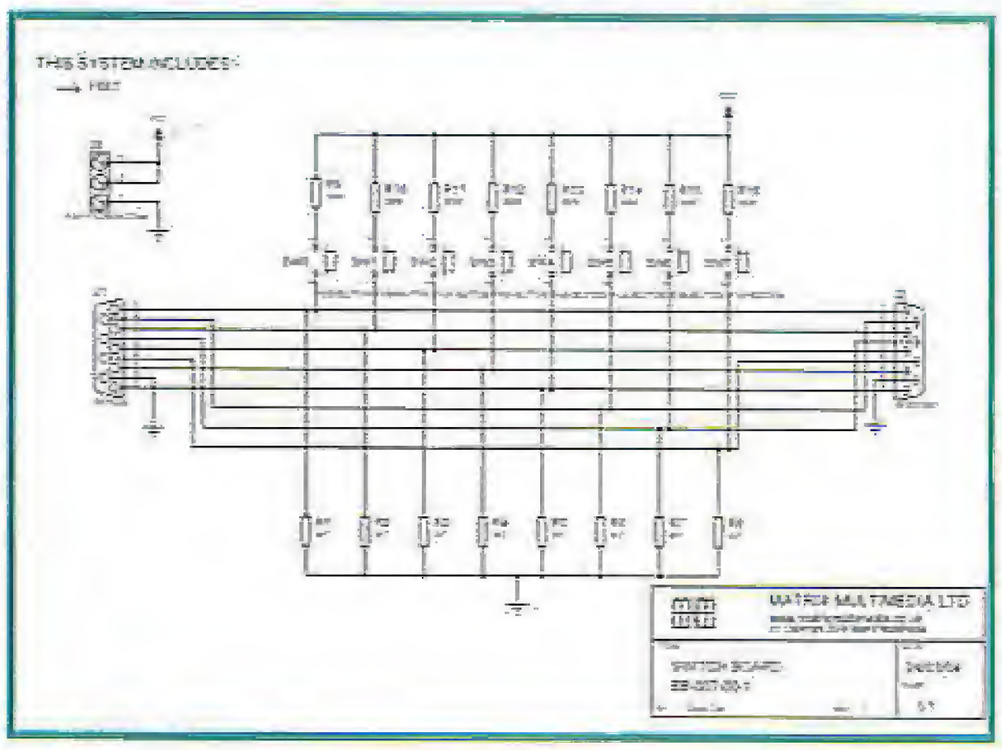


Figure 3. The 8-pushbutton switch board needs a power supply, to be taken from the +V terminals of the Multi-programmer board. The microcontroller inputs are pulled down by 4k7 Ω resistors and protected by 390 Ω series resistors. (Source: Matrix Multimedia)

System

Construction

Besides the Multi-programmer board, the experimental setup will include the 8-switch Switch board and the 8-LED LED board (**Figure 2**).
The E-Blocks Switch board in **Figure 3** needs powering via a wire from a +V terminal on the Multi-programmer board, connected to one of the +V terminals (OUT or IN, they are joined together).
These two circuits are taken from the CD-ROM by Matrix Multimedia.

At rest

Our setup will be using port B for the inputs and port A for the outputs. As per the flowchart in **Figure 4**, the program continuously monitors the state of bit 0 of port B. The test **if** decides if it is necessary to perform the relevant action for the case where the input (the Properties of which can be found in the screen dump in **Figure 5**) has gone high. If pin 0 of port A goes high, the program exits the small loop 'A' to perform the action requested ('output') and then return into the big loop: light the 'Armed' LED and set the variable ARMED to '1'. The screen dump in **Figure 6** illustrates the output properties.

Intrusion

Now the system is armed, it is necessary to enable it to react to an intrusion, which will correspond to the closure of a sensor contact. We enter a new loop, in which we shall need to verify the state of the sensors and the set/reset button. A 'high' on a sensor line will light the 'INTRUSION' LED connected to output 1 of port A. For the test, we shall only take into account input 1 of port B.

The screen dumps in **Figures 7** and **8** give the Properties of the input and output. The flowchart in **Figure 9** shows only the part of the full flowchart that we are interested in, i.e. from the point 'while ARMED <> 0', the rest being identical to the flowchart in Figure 4. This detection loop needs to be modified so as to take account of all the inputs to which sensors are connected. Two methods are available to us: adding fresh 'Input' boxes or adding bits in the 'Properties' of the existing box.
It's also possible to make provision for two 'Input' boxes, each monitoring one part of the sensors and triggering an action appropriate for the zone where the sensors are.

And back at rest again

All we now have to do is to exit the detection loop in order to clear the alarms and disarm the system. Here again, there are (at least) two solutions. We can simply add a test for the set/reset button. We can also – and this is what we are going to be doing here – make use of one of the 'properties' of port B: triggering an interrupt whenever one of the pins changes state. Pins 4 to 7 react to any change of state. Depending on its configuration, pin 0, labelled INT, reacts to either a rising or a falling edge. We configure it (Properties) to react to a rising edge on pin 0 and reset the variable 'ARMED' to zero (Macro). By so doing, the condition for remaining in the detection loop disappears and the program exits this loop. Before returning to the big loop, we take care to disable the interrupt RB0/INT, to extinguish the indicators and set a timer.
Two problems arise, which we shall solve in a single action. The first, and obvious, problem, is that once the

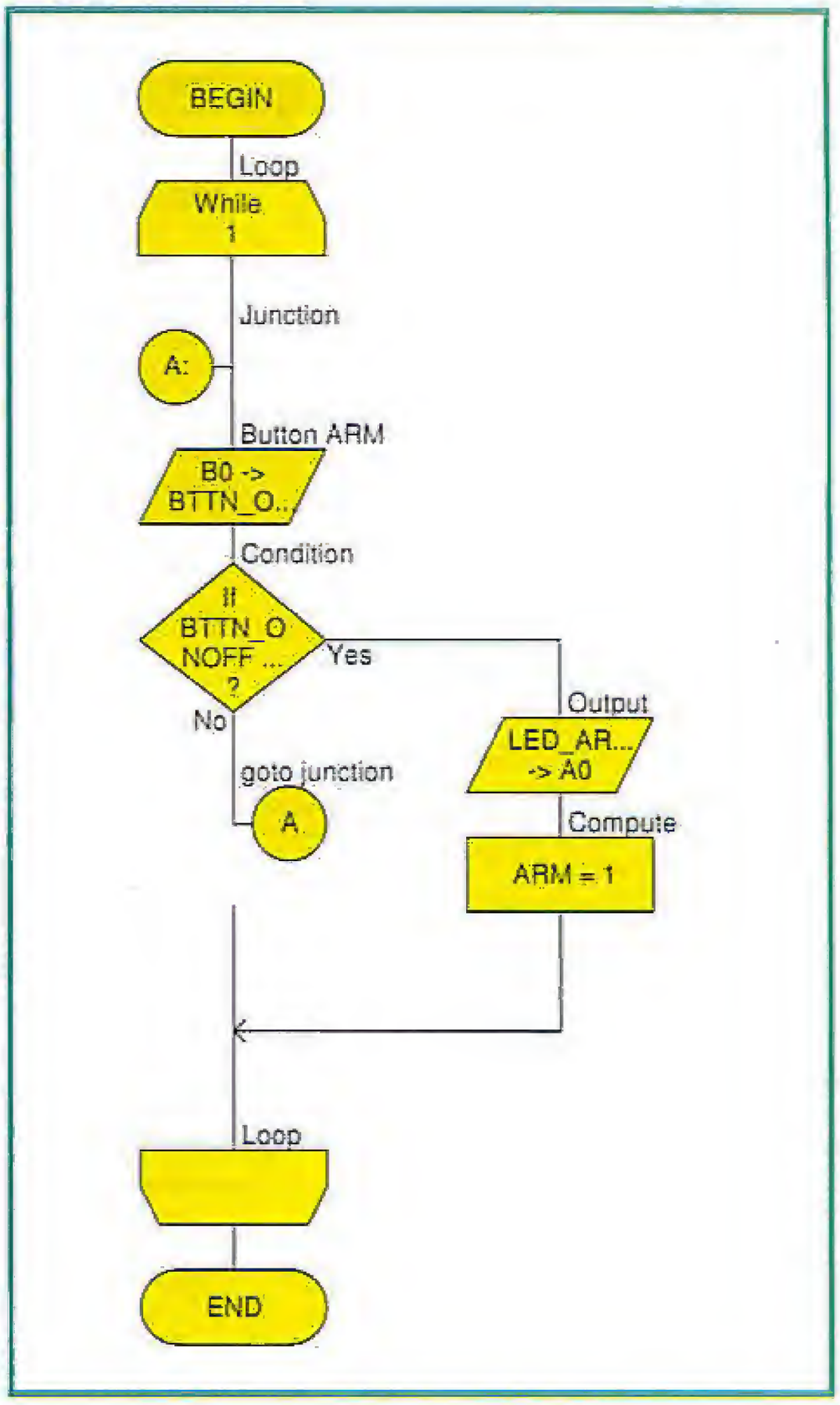


Figure 4. In stand-by, the system constantly monitors the set/reset button.

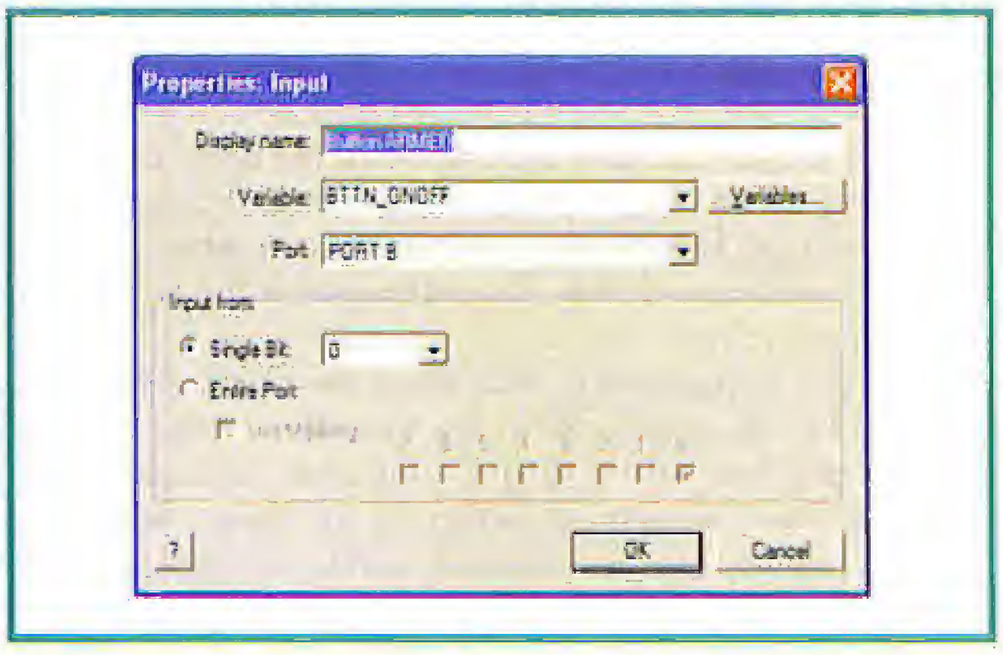


Figure 5. Input 0 of port B is the only one taken into account.

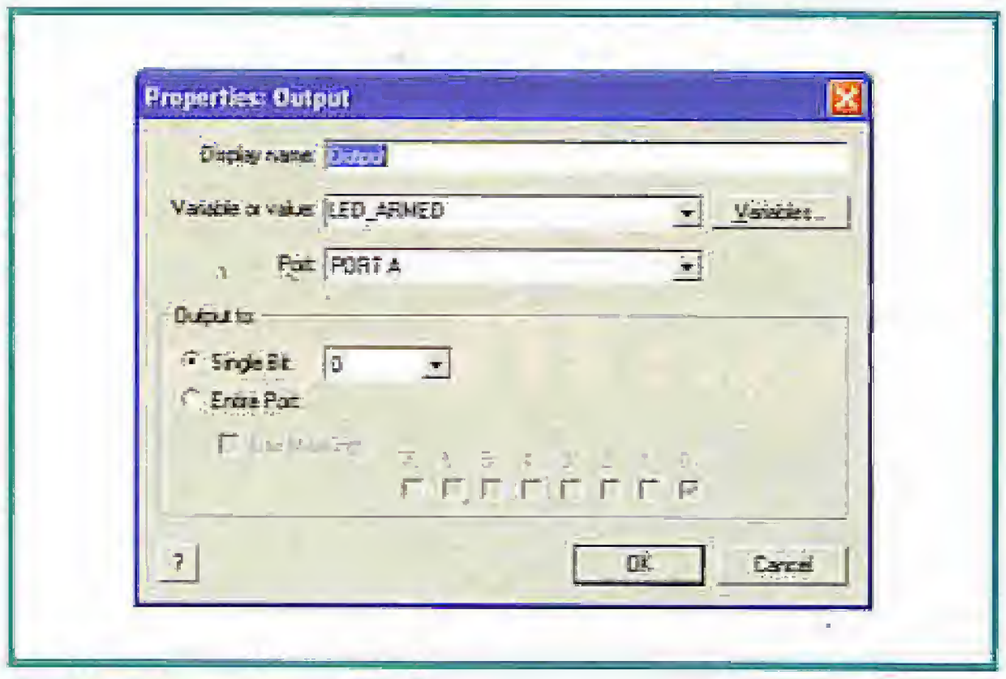


Figure 6. Output 0 of port A goes high to indicate the change of status.

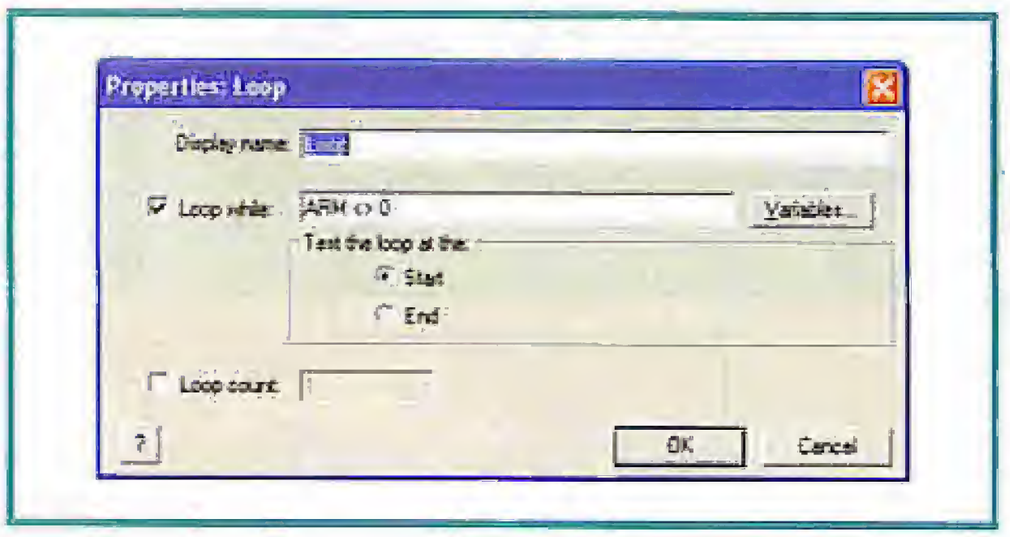


Figure 7. Input 1 of port B corresponds to the first sensor.

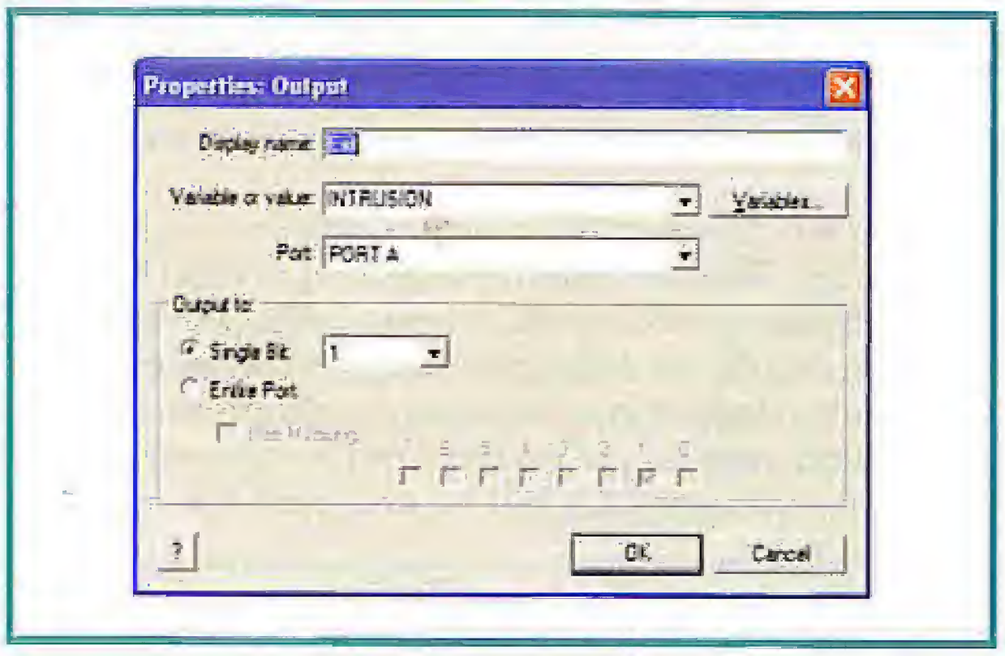


Figure 8. Output 1 of port A goes high to signal an intrusion.

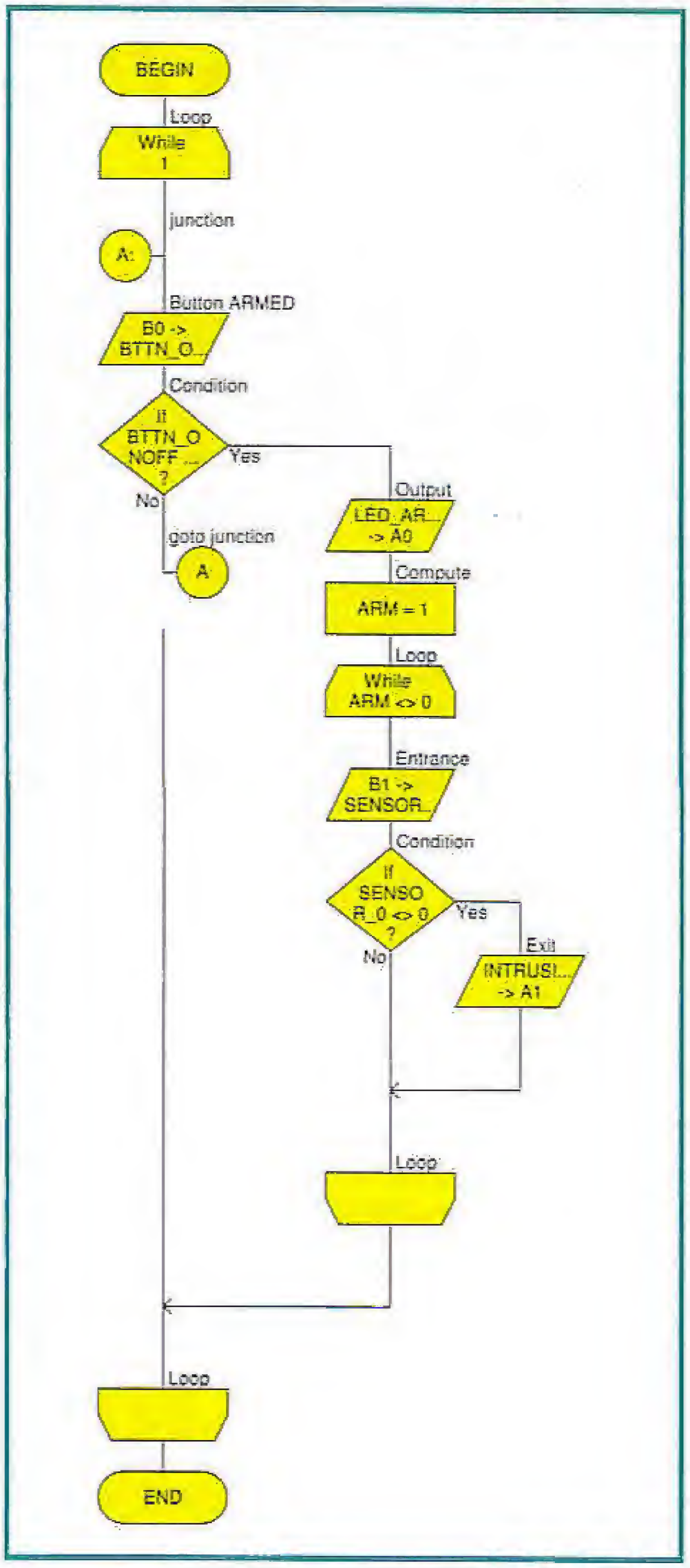


Figure 9. The intrusion detection loop has no end instruction. It will be necessary to cut the power to exit it.

system is armed, the user cannot leave the premises without setting off an alarm. The second is that, if pressure is maintained too long on the set/reset button when turning it off, this will immediately be interpreted in the big loop as a request to arm.
The solution is common to both these problems: time delays need to be introduced in the execution. After arming, a delay of a few tens of seconds will give the user time to leave the premises without setting off an alarm. After disarming, a delay of a few seconds will leave enough time to release the button and allow the inevitable mechanical switch bounce to stop.

The complete flowchart for the intruder alarm can be found in **Figure 10**.
Each of these delays is achieved using a countdown in the loop. A register is loaded with the number of seconds delay. An interrupt from the timer decrements the contents of the register. When the counter gets to zero, the program exits the wait loop. If there is nothing else to be done except wait, the rest of loop can be empty.

The variable 'RATE' (**Figure 11**) is a 16-bit number. In the microcontroller's default configuration, the internal oscillator has a frequency of 19.6608 MHz. Pre-division by 256 yields a signal at 75 Hz to clock TIMER0. 75 zero

transitions, and hence 75 interrupts, are needed for a delay of one second. The counter is loaded with the number of clock pulses instead of the number of seconds. The number of seconds appears in the flowchart – the multiplication by 75 is left to the compiler. It is also possible to create an auxiliary variable that would count 75 interrupts before counting down RATE.
The macro 'Tictac', called by the interrupt, counts the overflows of the counter-timer TIMER0. The C instructions contained in this macro/command are:

```
if (FCV_RATE > 0) FCV_RATE = FCV_RATE - 1;
// Count down
if (FCV_RAYE %75 ==0) FCV_LED_ARMED=1;
// Detection very second
```

Output

During the delay period after arming, LED A0 will flash at 1 Hz. To achieve this, the status of the flag LED_ARME is tested in the loop. This flag is set when the value of the counter TEMPO is divisible by 75 (modulo operation above), i.e. when we are at a round second. In this case, the value of A0 is read, is inverted by the exclusive OR operation, and is brought out on the A0 output pin. Once it has been used to decide the branching, the LED_ARMED byte can be used as an auxiliary variable. In this series of operations, one piece of good programming practice may be noted: the flag that triggers output switching is set by one function, the interrupt routine, and reset by another function, the output switching routine. Poor practice would have been to set and reset the flag within the same routine, which would run the risk of giving random flashes. The LED will be lit at the exit of the loop, whatever state it was in before.

Extensions

To complete the burglar alarm, all that remains to be done is to increase the number of sensors being monitored and add a few hardware elements. First of all, one or more relays, connected from the output pins via transistors, to signal the alarm in a more dramatic fashion than by an LED; then the incoming lines for connecting the sensors, with the necessary protection against overvoltages and induced voltages.

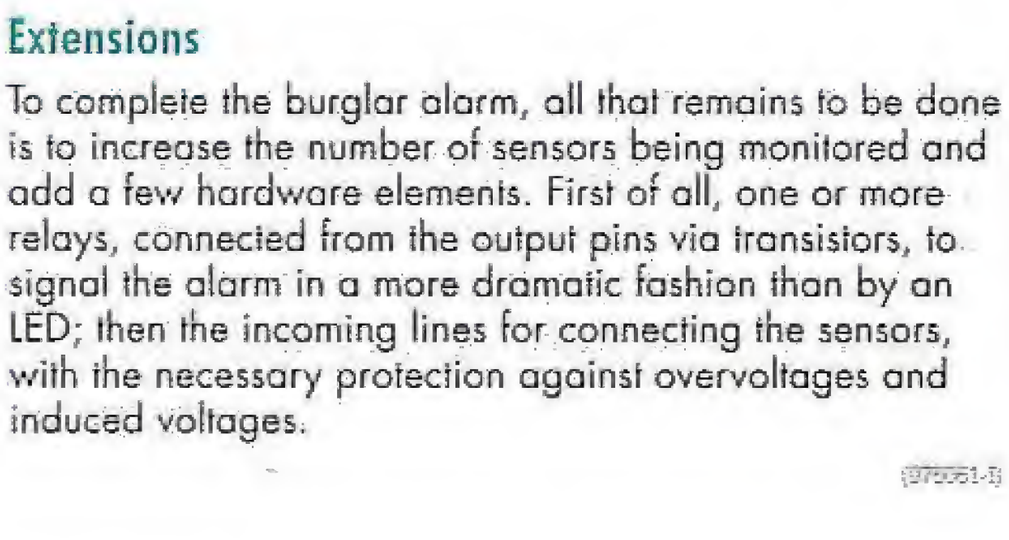


Figure 11. The variable RATE keeps count of the seconds of the delay.

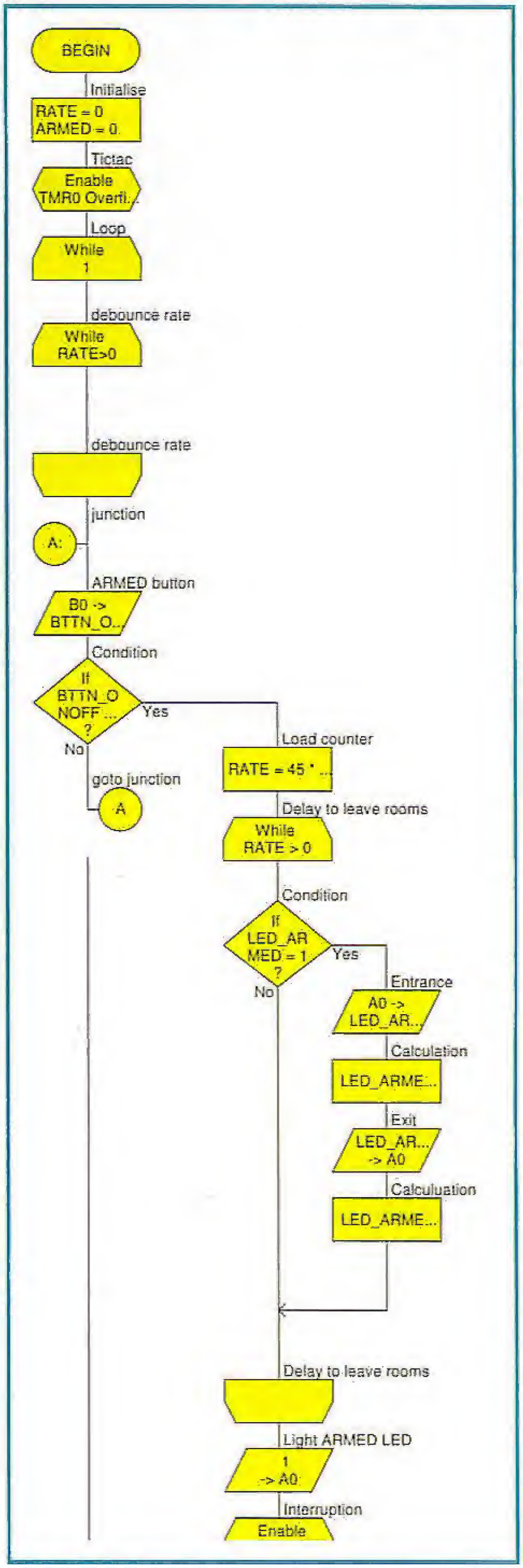


Figure 10. Extract from the intruder alarm program.

Reliable Finge

A sensor that reads fingerprints using RF signals

Security is becoming an increasing important topic nowadays. Protection of personal data in particular is receiving a lot of attention. Fingerprint sensors are thus riding a rapid development trend. The ESCO Biometric DigitalisS is an unusual type of fingerprint sensor system. It uses RF signals to record fingerprints.

The first fingerprint sensors, which were developed around 1990, used surface contact methods to record the unique patterns of fingerprints. The predecessors of current methods used optical imaging methods to produce pictures of fingertips.. A number of different methods are now available, each with its own advantages and disadvantages.

Methods

One example is electrical capacitive measuring, which uses charge-sensitive sensors to detect the differences between ridges and valleys. The disadvantages of this method are its sensitivity to static charges and the fact that its electronic circuitry can be tricked relatively easily by using an artificial finger.

Another method is based on using piezoelectric sensors to measure pressure. The disadvantages of this method are its low sensitivity, its inability to differentiate between real and false fingerprints, and its sensitivity to excessive pressure.

A third method is thermal recording. A pyroelectric material can convert the difference between the temperature of a pixel element touching a ridge and the temperature of an element located beneath a valley into a voltage. This technique is nearly foolproof. However, it has the disadvantage that the thermal image disappears within one-tenth of a second. The sensor array is heated quickly by the finger, with the result that there is no longer any temperature difference.

Optical detection, which is the method that was first used to record fingerprints, is also still used. A picture can be taken using a CMOS or CCD sensor array and then converted into grey tones. The disadvantage of this method is that impression left by the finger can be reused. It is also difficult to distinguish a real finger from a good imitation.

The method used in the DigitalisS system is based on RF signals. A low-intensity RF signal is applied to the fingertip, which causes it to act as an antenna. A properly configured miniature antenna array can then use the RF signals to map the ridges and valleys of the fingertip. It is difficult to trick this sort of sensor, since its operation is based on the physical properties of the skin. The weakness of this method is the quality of the connection between the finger and the contact that transfers the RF signal to the finger. The contact point can also become very hot.

TruePrint

The American company AuthenTec has developed sensors that utilise the RF signal method. The technology they developed, dubbed 'TruePrint', works by reading the fingerprint from the live, highly conductive layer of skin cells just beneath the dry outer surface layer (see **Figure 1**). This method is relatively insensitive to dry, abraded, raw, dirty or greasy fingertips, which can confuse other types of sensors. The false acceptance rate (FAR) is 0.01%, while the

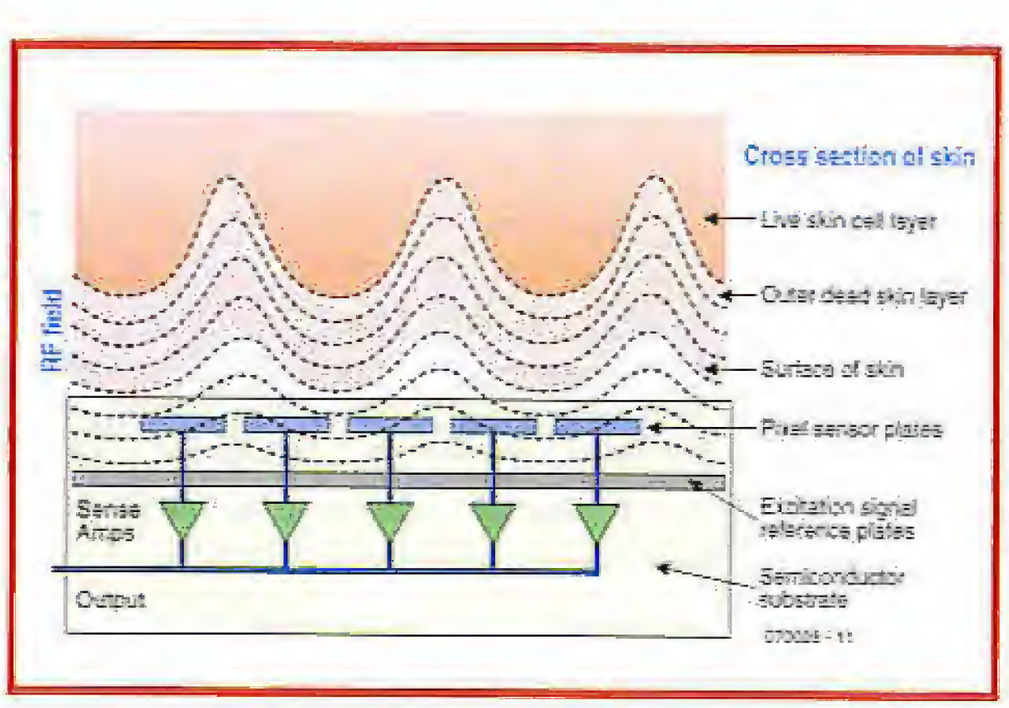


Figure 1. TruePrint technology uses RF signals to read fingerprints.

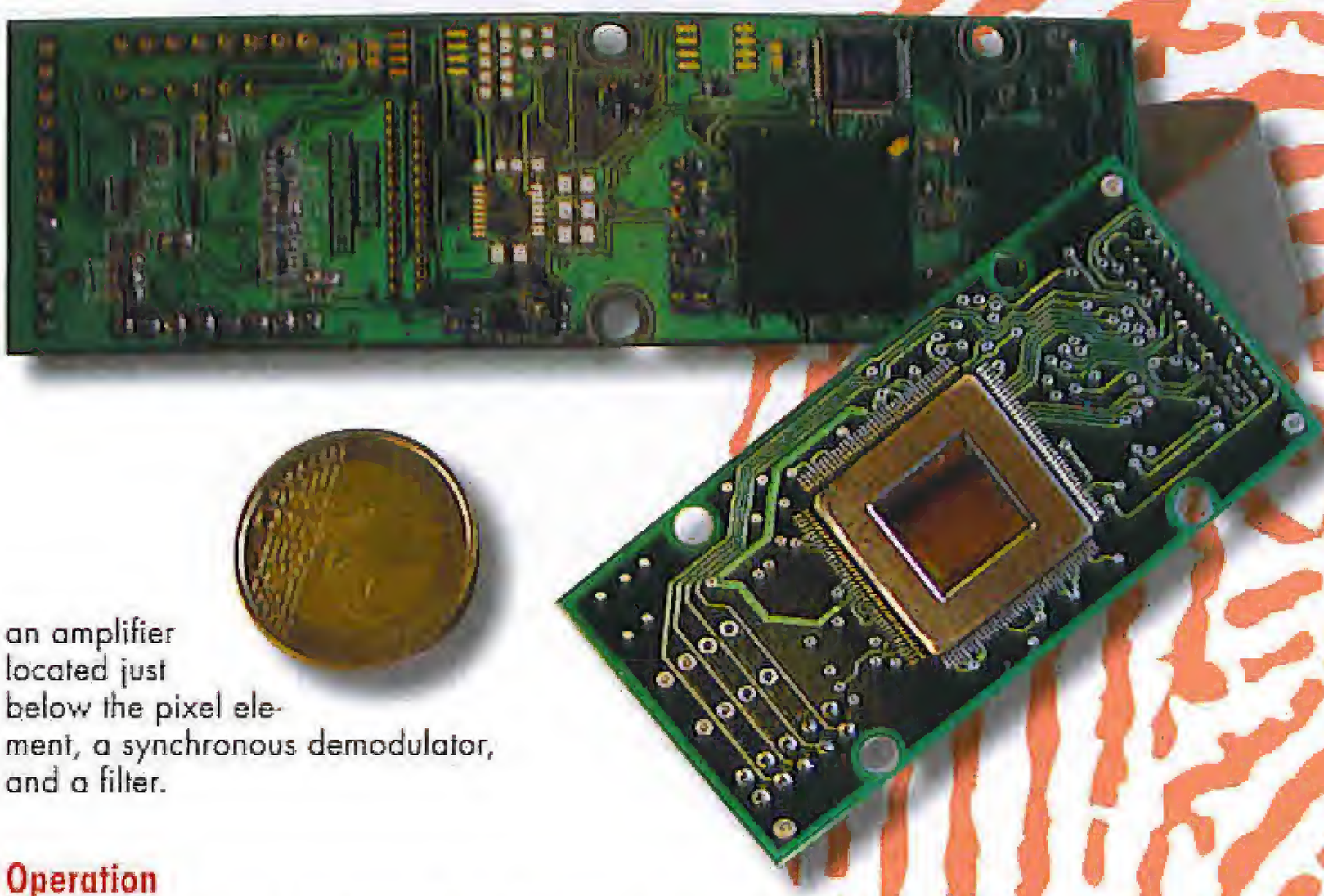
false rejection rate (FRR) is 0.10%.

The DigitalisS system made by ESCO Biometric uses the AFS8600 sensor, which was developed by AuthenTec and is based on TruePrint technology. It consists of a sensor array, a drive ring, and the associated electronics. The electronics detects the presence of a finger on the surface of the sensor and produces a digital image of the fingerprint.

The square sensor array is located in the middle of the chip, and it has an edge dimension of 11.43 mm. This sensor array is actually the top surface of the chip. The surface is treated with a special ceramic coating with a Moh hardness of 7+. This protects the chip against abrasion and wear.

The array is formed by 9216 individual elements arranged in a 96 x 96 matrix. This arrangement is divided into six rows of 96 x 16 pixels. Each element has

rprints



an amplifier located just below the pixel element, a synchronous demodulator, and a filter.

Operation

The elements in each column of a subarray are scanned to generate a digital image. A 16-channel multiplexer selects each column of the subarray in turn for sampling and digitizing, The selected column drives an analogue bus line. The signal is amplified, integrated, and fed to a sample-and-hold circuit. The resulting analogue signal is then digitized.

The drive ring transfers the signal to the finger, which means it must make contact with the finger for proper recognition. Consequently, it is located around the periphery of the sensor array. It can be recognised by its slightly lighter colour. The drive ring is driven by on-chip direct digital synthesis (DDS) components that generate a sine-wave signal. The phase, frequency and amplitude of this signal are determined by software via the control registers of the sensor.

The sensor array is actually a set of active antennas that pick up the very weak signal transmitted by the drive ring. The signal from the drive ring is coupled into the user's finger, and it is modulated by propagation through the various layers of the skin. This means the finger must make contact with the drive ring and the sensor at the same time in order to generate a pattern corresponding to the fingerprint of the dermal (live) layer of skin cells. AuthenTec has integrated a temperature sensor in the fingerprint module to avoid generation of an excessively hot contact spot due to the resistance between the finger and the drive ring. It monitors the temperature and switches off the module if the temperature becomes too high.

Recognition

The recognition process can start after the data has been recorded digitally. This process involves several steps. First the data must be converted into a manageable format. A commonly used method, which is also used by the FBI, is to identify the 'minutiae'. These are special features in the pattern of the lines of a fingerprint, such as branches and intersections. A unique 'signature' specific to a particular person can be composed from 40 points. Determination of the positions and orientations of the minutiae is sufficient for comparison of different fingerprints. As a result, a unique fingerprint occupies only 128 bytes in the digital domain.

This digital information can be compared with information in a database. Although each sensor manufacturer uses its own algorithms, they are all based on the same basic principle, which is to look for the best match. All sorts of circumstances can occasionally cause slight differences between the stored and measured images of the minutiae. For this reason, each algorithm usually has a configurable error tolerance, which also directly determines security level. This is of course directly related to the FAR and FRR values of the system. The more stringent the security level setting, the more often fingerprints will be rejected. Although it may be acceptable to let your fingerprint be scanned 15 times for access to a top-secret government facility, this would be far too inconvenient for consumers who want to use fingerprint identification for paying at a filling station. Everyone benefits from a fast, accurate detection system, and TruePrint technology provides a solid basis for such a system.

(070028-1)

Web links:

www.escobiometric.com

www.authentec.com

Simple DIY Programming

Poor man's AVR flash programmer

Like it or not, the microcontroller has become an indispensable part of electronics. However, there are still people who know very little about these components. For this reason alone, many people avoid building various projects. The problem is often the programming of the microcontroller. Buying it is one thing, but programming the firmware...

Jeroen Domburg & Thijs Beckers

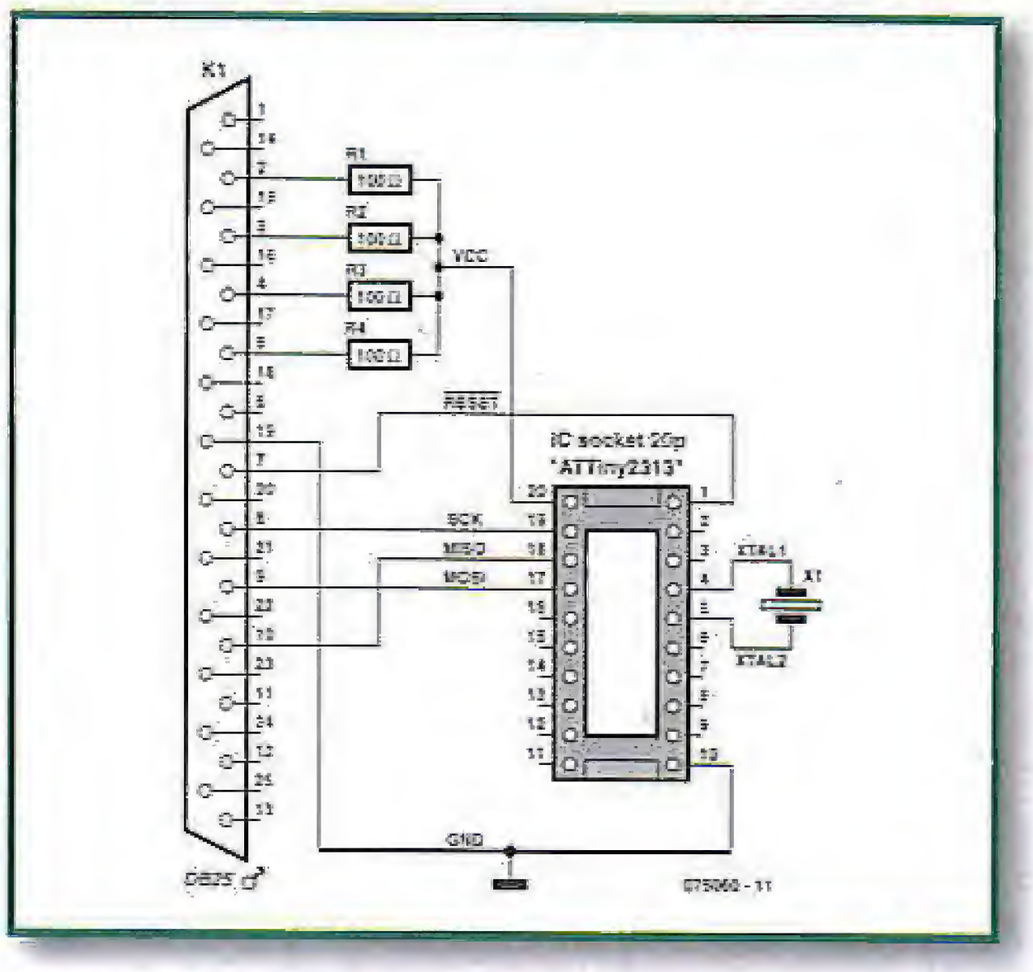


Figure 1. The 'schematic' is really nothing more than a few wires and a socket for the microcontroller.

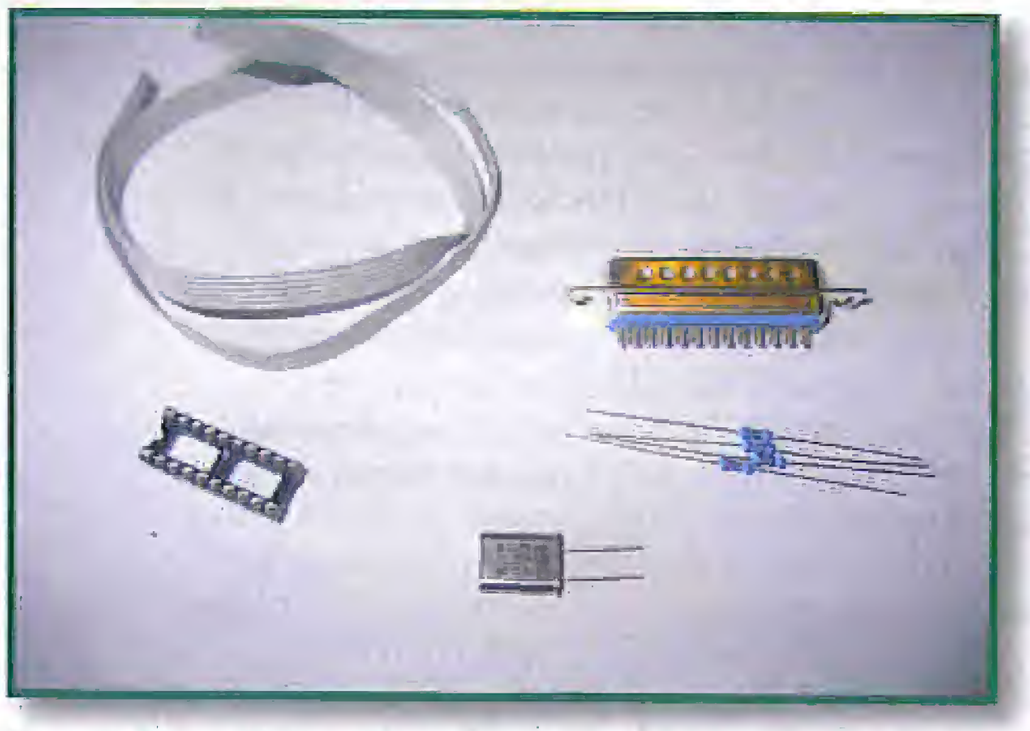


Figure 2. We usually keep the number of parts to a minimum. But this time there are very few indeed...

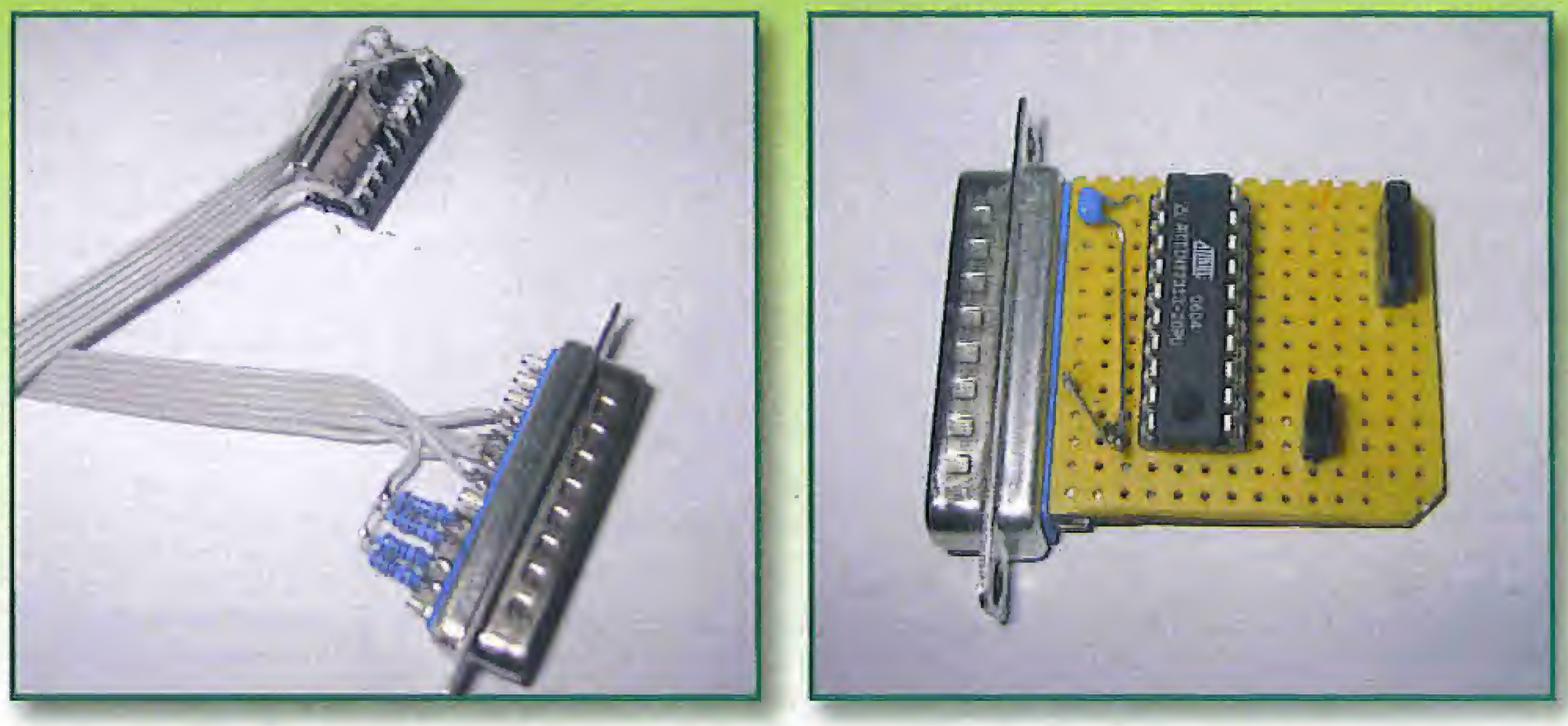
The main reason for people to avoid a microcontroller based project is the obstacle of 'programming the thing'. The expectation is often that an expensive programmer is required to program microcontrollers. This is fortunately not always the case. Although there are a few, usually older, microcontrollers that require a professional (and expensive) programmer, making a good programmer yourself for most modern microcontrollers is a matter of only a few quid. In this article we look at a programmer that's specifically suited for the AVR series of microcontrollers from Atmel. It can program practically all AT90, ATTiny and ATMega chips. AVR, by the way, means... nothing.

Protocol

In addition to complicated and faster protocols, most AVR microcontrollers also support the slower ISP protocol. ISP stands for In System Programmable and has been specifically designed to (re-)program an AVR micro without having to remove the chip from the circuit. This does make it necessary that a few pins are reserved for the programming operation. Preferably not too many, because that is not convenient if the controller has already been fitted in a circuit. Atmel has been able to limit the protocol to five signal lines: Reset, MISO, MOSI, SCK and GND. With this information we can get started.

Design

There is no need for special (high) programming voltages, so if we can generate the correct signals we are actually done. The PC has a port that makes it easy to generate TTL compatible signals: the parallel (or Centronics) port. It is therefore obvious that we use this port for our 'programming adapter'. The pins can be directly connected to the AVR micro. The supply voltage we also 'steal' from the parallel port. With a few 100-Ω resistors we join a few pins from the parallel port together (see **Figure 1**). We connect all this to an IC socket for the AVR micro to be programmed. Use a somewhat more expensive, turned-pin socket. These last a lot longer than an ordinary socket, which tends to have rather soggy springs after only a few uses.
We still miss one part. Some microcontrollers have a built-in oscillator, but most of them need a quartz crystal to generate the clock frequency. We therefore have to add that to our 'circuit' as well. Because the programming is done with a clocked signal, the value of the crystal is not very critical . Any value from 4 MHz up to the value that the AVR micro is rated for, can be used. We should also connect two capacitors of 22 pF to ground, but we leave those out for simplicity. We have never



The construction can be done two ways: on the left the simplest way and on the right the version with a small PCB.

had any problems because of this. You can always add them later if they turn out to be necessary after all.

Software

The (free) software that we use with this programmer can be found under the name of 'AVRDUDE' (AVR Downloader/UploaDEr). The software was originally made to operate in a Unix environment, but a number of fans have written a version for Windows. The programming software is bundled with the free package 'WinAVR' [1]. In addition to AVRDUDE WinAVR also contains a compiler, an assembler and other programming tools. We don't need these, however, if we only want to program the firmware in an AVR microcontroller.
AVRDUDE has been designed for Unix-based operating systems. If you are running such an operating system on your computer than you will have no problem programming an AVR microcontroller using the manual.
However, AVRDUDE does not have a user interface that Windows users expect. This can be solved with the package 'AVRDUDE-GUI' [2] (GUI means Graphic User Interface). After downloading you need to unpack the files from this package into the same folder that contains AVRDUDE, usually C:\winavr\bin. The program starts with a double-click on avrdude-gui.exe and you can now easily adjust all the parameters.

An example

As an example, we wish to program the code for the Ethermeter (*Elektor Electronics* March 2007) in the AVR microcontroller. What things have to be set? Firstly, it is *device*. Here we choose the 'ATTiny2313' as that's the controller we are going to program. The 'programmer' we describe in this article is the so-called 'bsd' programmer, so we select it. After that, we have to select the port we're using. In our case, it's the printer port, that is, LPT1. Unfortunately, AVRDUDE in combination with this interface can only drive parallel ports that are mounted directly on the motherboard of the PC. USB to parallel adapters never work and with PCI expansion cards there is a good chance that they don't work either. So, it will often be the case that you need to select 'LPT1' in the 'Port' box.
Now we can configure the AVR settings themselves. We want to flash a file, so tick the 'Flash box called 'Write' and below that indicate where the hex file is. With the '...' button you can browse to the correct location, if necessary.
Usually we also have to set the fuses. The settings are normally in the article or in the source code for the program (the .asm or .c file, which is often available as a download). The fuses have to be entered in hexadecimal form. If the values are indicated in a different way then we can convert them with the on-line fuse-calculator [3].
In the case of the Ethermeter, the .asm file states that the low fuse has to be '0xcf' and the high fuse, '0xdf'. With both we tick the 'Write' box and enter the appropriate values. If all is well, the window will look about the same as the one shown in **Figure 4**.

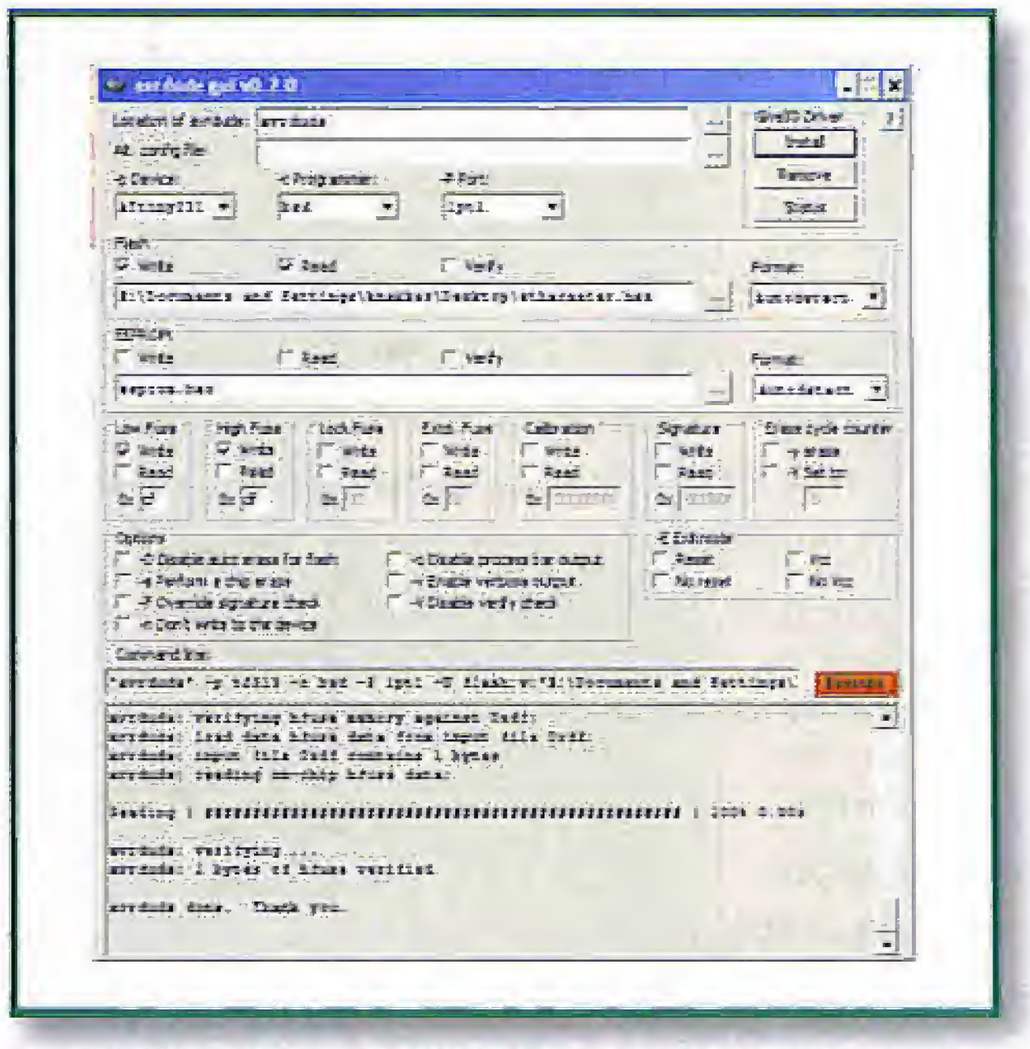


Figure 4. This is the way AVRDUDE-GUI needs to be set to program the Ethermeter firmware.

To program the AVR, AVRDUDE needs access to the parallel port. This cannot happen just like that in modern Windows versions — it requires a special driver. Fortunately, installing this driver is not too hard: click the 'Install'-button in the box 'GiveIO Driver' at top right and it will work.
Now that just leaves clicking the 'Execute' button and the AVR micro will be programmed. The box at the bottom indicates the status. If all goes well the software will indicate here that everything was a success. You can now remove the microcontroller from the programmer socket and fit it in the circuit.

Finally

This article is written with an ATTiny2313 as an example. The programmer also works with other Atmel AVR microcontrollers, even those in a larger or smaller package and with a different number of pins. Refer to the datasheet which pins are MISO, MOSI, SCK, Reset, VCC and GND and connect these to the correct wires. Remember to select the appropriate chip in AVRDUDE-GUI.
Now, a final tip: when downloading the graphical interface, check that you have the latest version. Earlier versions contain bugs, such as the incorrect interpretation of the fuse bits. Take a look at [4] for more information.

(070360-I)

Web links:

[1] http://winavr.sourceforge.net
[2] http://sourceforge.net/projects/avrdude-gui
[3] http://palmavr.sourceforge.net/cgi-bin/fc.cgi
[4] http://sprite.student.utwente.nl/~jeroen/projects/avr_stuff

About the author

Jeroen Domburg is an electrical engineering student at the Saxion technical University in Enschede. He is an enthusiastic hobbyist, with interests in microcontrollers, electronics and computers.

In this column he displays his personal handiwork, modifications and other interesting circuits, which do not necessarily have to be useful. In most cases they are not likely to win a beauty contest and safety is generally taken with a grain of salt. But that doesn't concern the author at all. As long as the circuit does what it was intended to do then all is well. You have been warned!

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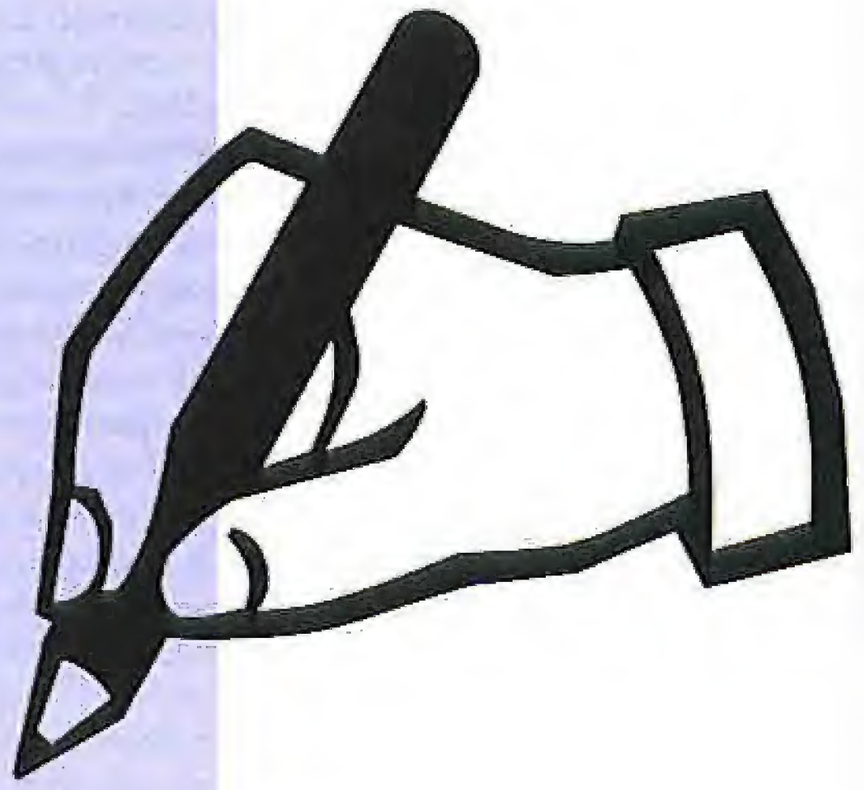

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SDR Soundcard Tester

Burkhard Kainka

The key to using a soundcard successfully in digital signal processing or digital radio applications lies principally in the characteristics of the soundcard itself. This applies in particular to SDR (software defined radio) programs that turn your PC into a top-class AM/SSB/CW receiver, assuming your soundcard cooperates. If you want to experiment with SDR and avoid a lot of frustration, it is worth checking first whether the PC soundcard you plan to use is suitable. There are three essential elements to success:

- the soundcard must have a stereo line-level input;
- the card must be equipped with an input anti-aliasing filter; and
- the sample rate must be at least 48 kHz and the card must be able to cope with signals up to 24 kHz.

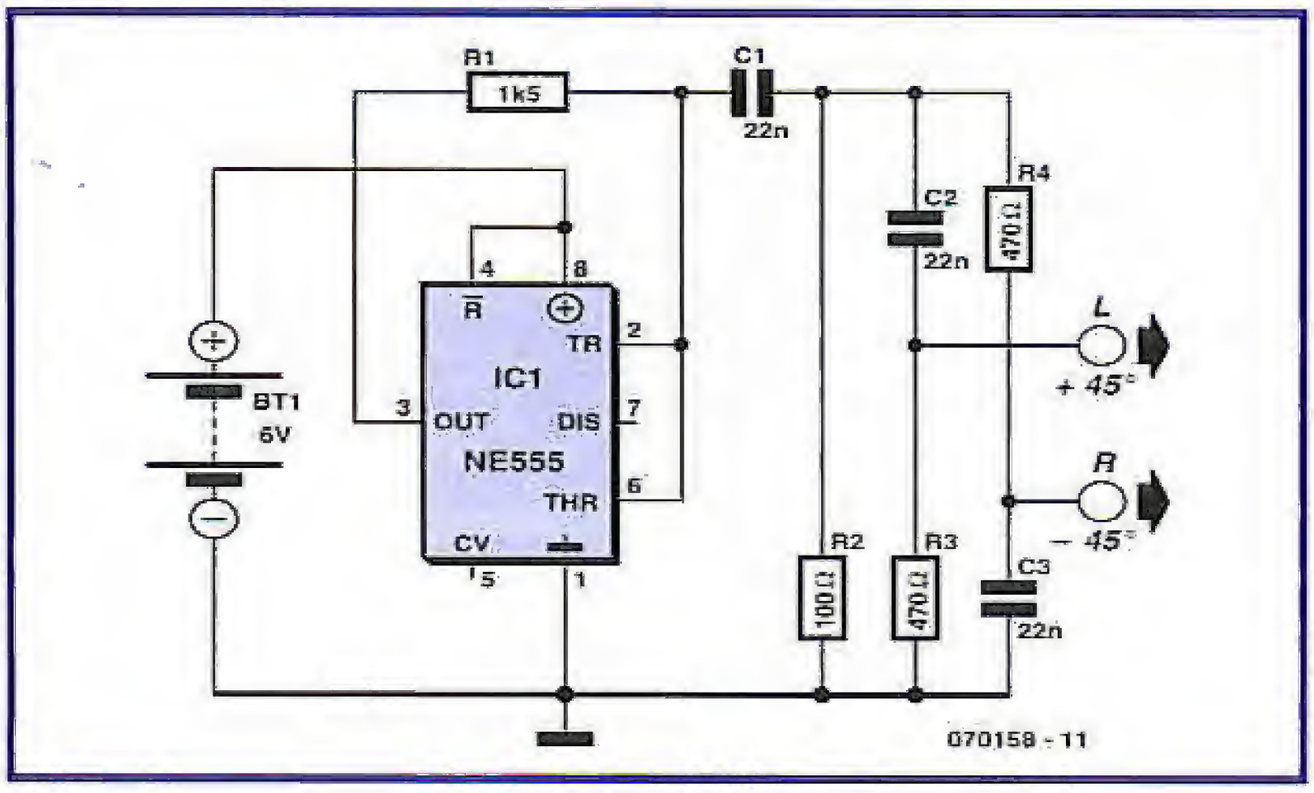

Figure 1. The test circuit to generate I and Q signals.

Figure 1 shows a simple square-wave generator built around an NE555 timer IC. At the output is a 15 kHz signal rich in higher harmonics. Using this we can determine whether or not the soundcard can process the harmonics at 30 kHz, 45 kHz and so on. An anti-aliasing filter at the soundcard input should attenuate all signals above 24 kHz. The frequency of the test generator is, within limits, dependent on its supply voltage. Using an adjustable power supply, a frequency range from 10 kHz to 20 kHz can therefore be covered.

There are two RC networks at the output of the test circuit, a high-pass filter and a low-pass filter, acting as simple phase shifters. At the basic frequency of 15 kHz these provide a total phase difference of 90 degrees, corresponding exactly to the typical situation at the output of an SDR receiver circuit using an I-Q mixer: signals at the same frequency but differing in phase. To test the soundcard we need an SDR program running on the PC as well as the circuit of Figure 1. Suitable software includes SDradio (available for download from http://digilander.libero.it/i2phd/sdradio/). When things are running correctly, the screen should display just two signals: the wanted signal at 15 kHz and a weaker image at –15 kHz (**Figure 2**). Suppression of the image may not be particularly good as the test circuit does not have very high phase and amplitude accuracy. If, however, the signals have the same level, there is a problem in the processing of the two channels: it is probable that the soundcard only has a monophonic input.

If there is no anti-aliasing filter at the input of the soundcard the spectrum will show a large number of extra lines (**Figure 3**): it is easy to work out which harmonic corresponds to which alias frequency. The results obtained using an I-Q receiver were grim: frequencies all the way out to 100 kHz were wrapped into the audible range, resulting in bubbling, hissing and whistling.

Many laptops have only a mono microphone input, sometimes also rather limited in bandwidth. In this case it may be possible to use an external USB soundcard.

Most desktop PCs these days have an internal integrated soundcard, although some of these do not feature an anti-aliasing filter. Attempts to disable the integrated soundcard and replace it with a better one often meet with failure; again, an external USB soundcard is a possible solution.

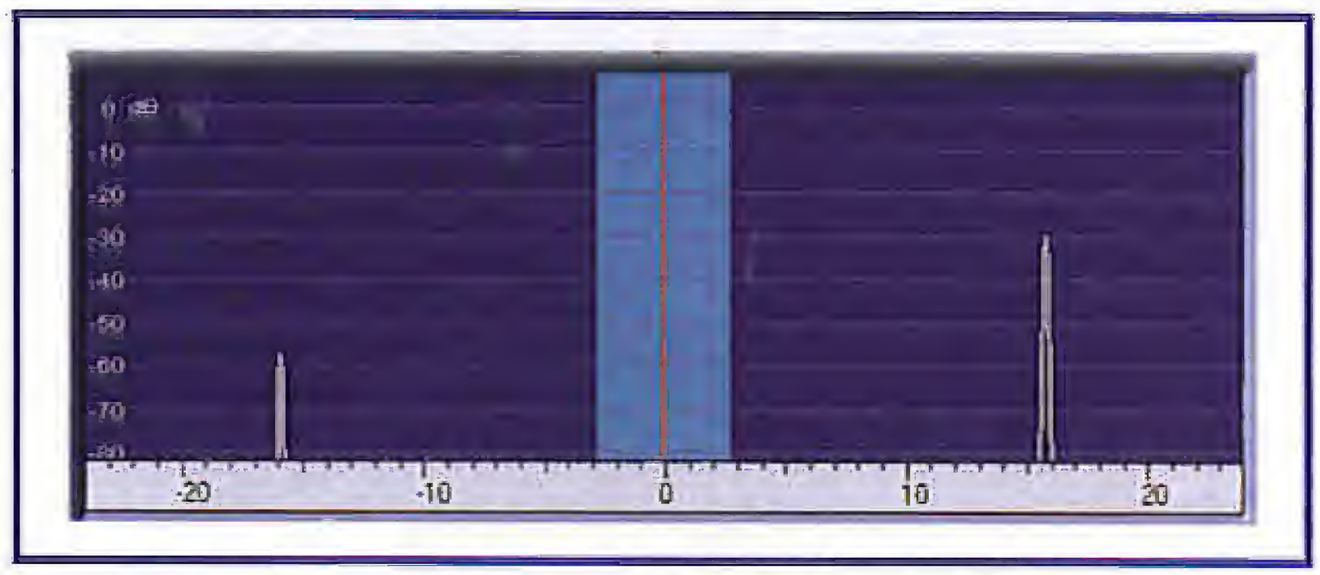

Figure 2. Test passed!

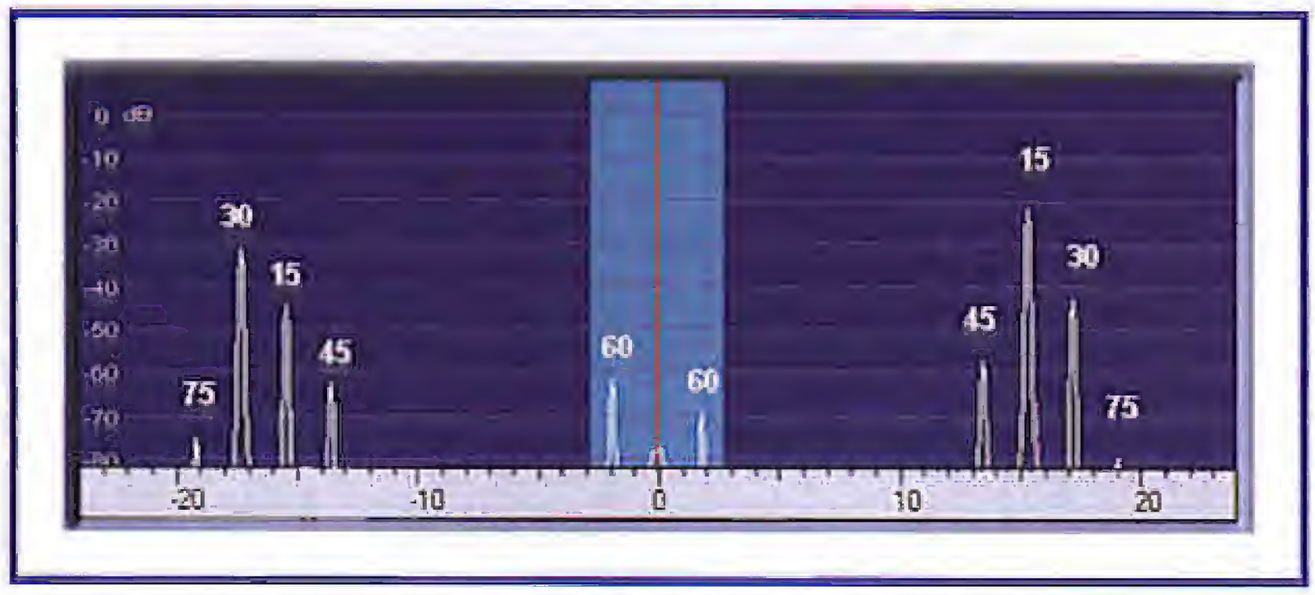

Figure 3. A soundcard without an anti-aliasing filter.

Test circuit

To avoid guesswork, the best way to proceed is to test the soundcard using this very small circuit. This will help to diagnose any problems and will help determine whether the card is suitable for use with an SDR program.

In theory it would be possible to add an anti-aliasing filter to the output of the receiver to allow use with soundcards that are not equipped with such a filter. In practice, however, it is not easy to achieve the required sharp cutoff and symmetry between the two channels. A typical soundcard has a low pass filter set at 24 kHz which by 27 kHz is already attenuating the signal by some 60 dB. This is only practical using digital filters; an adjustable analogue circuit to achieve this performance would be so complex that the simplicity benefits of SDR receiver technology would entirely evaporate.

(070158-I)

Hexadoku

Puzzle with an electronic touch

It should be summertime when you read this, and a fine opportunity to have a go at solving another Hexadoku puzzle. Get yourself installed on a quiet terrace with a drink within easy reach and spend some time cracking Hexadoku. Who knows, your efforts may be rewarded with an E-blocks Professional Starter kit or one of three Elektor SHOP vouchers.

The instructions for this puzzle are straightforward. In the diagram composed of 16 x 16 boxes, enter numbers such that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once only in each row, once in each column and in each of the 4x4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle and these determine the start situation. All correct entries received for each month's puzzle go into a draw for a main prize and three lesser prizes. All you need to do is send us the numbers in the grey boxes.

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6			3				9		0	4	1	8	E	2	
0	9							6		E				7	
		2		8		E	3		C	A					5
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Type 1650-A Impedance Bridge (1960)

Jan Buiting

This dull green test instrument produced by the General Radio Corporation is unremarkable for its application range (basically, it's a portable LCR meter) but fairly unique for its mechanical construction and low power consumption.

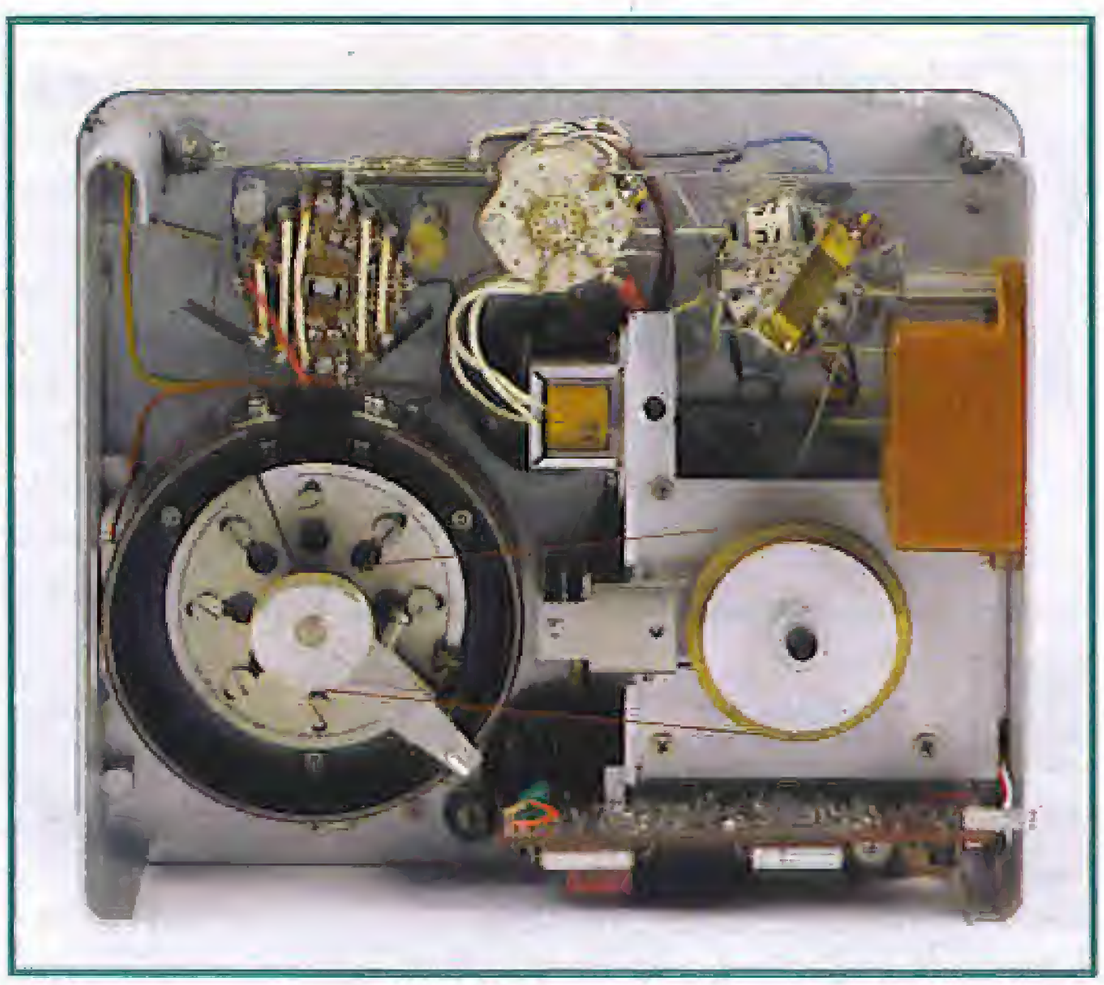
According to the 1960 manual, the 1650-A is a "*self-contained impedance measuring system, which includes five bridges for the measurement of capacitance, resistance, and inductance, as well as the generators and detectors necessary for dc and 1-kc ac measurements*". In 1960, a 1650-A without optional accessories would have set you back just shy of one thousand US dollars.

The bridges are claimed to achieve one-percent C, R, and L accuracy over all ranges, and "high" accuracy for D and Q. While I'm familiar with most of these parameters of passive components, it took me a while to figure out what 'D' stood for. Fortunately the 1650-A manual was produced by GRC to almost scientific standards when it comes to explaining the operation and theoretical backgrounds of the instrument (a rare thing these days), and 'D' was found on page 2 to stand for 'dissipation factor = R/X = 1/Q. Okay, so the worse the quality factor of an inductor or capacitor (!), the higher its dissipation. Fair enough.

The explanation of the symbols used neatly precedes a hefty section in the manual on the mathematics behind each of the five bridges in the instrument. I'm sure the production of these pages sprawled with complex-number mathematics, symbols and equivalent circuits for all R, C and L components and their bridge configurations was major effort if not a hellish job. Again, rarely seen in these times of *flip the switch & return to shop if it don't work*.

In the case of the 1650-A, an unusual method of opening and tilting the cabinet is required before you can flip any switches at all! Fortunately, the relevant instructions are printed on the handle support of the instrument, and we've tried to capture the momentous procedure (because that's what it is) in a few photographs printed here. In good US fashion, the construction of the arms and associated assembly to lift and tilt the instrument are protected by a patent. Due to the carefully chosen centre of gravity of the instrument proper, and its connection to the lift arms, it is almost impossible to damage the front cover or any of the front panel controls by improper handling. The instrument just opens up intuitively and is very secure in place in actual use as well as in transport. Unfortunately, the latter is not true for this particular 1650-A, which has two locking slide pins missing on the tilt arms — these parts I hope to machine myself from steel stock.

Although the 1650-A has all the features of a tube-based boat anchor, it is in fact powered by four 1.5-volt 'D' cells, which slide into a tube inside the instrument through a cap at the top. Remarkably, the battery holder was totally free from the usual white 'growth' produced by leaking batteries left to their fate for 20 years or so in a damp cellar. The 1650-A has a mere current consumption of 60 mA max. for all dc measurements (except low-value R's) and 60 mA for ac measurements. The secret: a transistorised circuit mounted on a 'printed wiring board (PWB)'.



A video clip showing the GRC 1650-A in actual use in the Elektor lab will be available from our website.

Thanks are due to Mr. Cor de Boer for putting this instrument to my disposal.

(075064-1)

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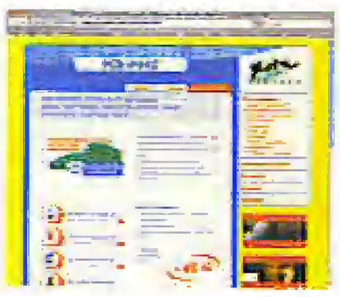

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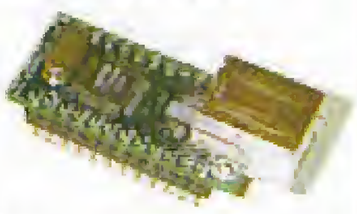

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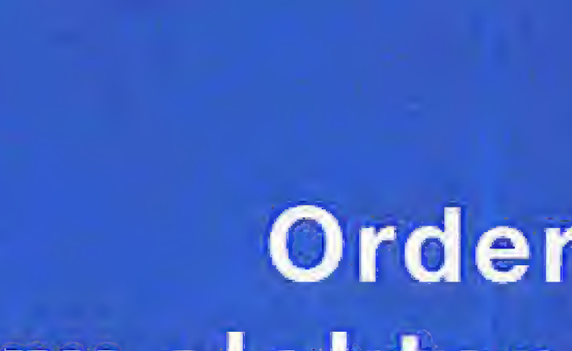

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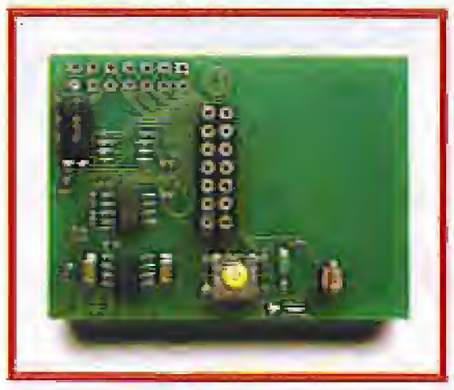

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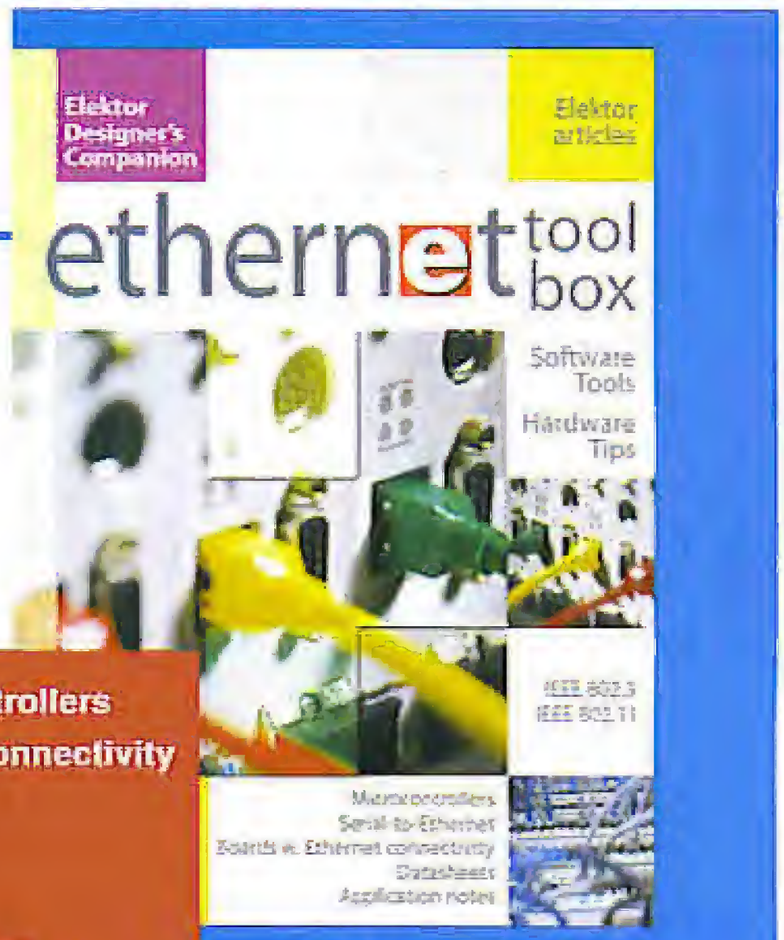

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